FISHERY RESEARCH

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

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LAKE PEND OREILLE FISHERY RECOVERY PROJECT

Project Progress Report

1999 Annual Report

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ABSTRACT

The minimum water level of Lake Pend Oreille was raised from 625.1 m to 626.4 m elevation during the winter of 1998-99 in an attempt to recover the impacted kokanee *Oncorhynchus nerka* fishery. This report covers the third year of testing higher winter levels. Hydroacoustic surveys and mid-water trawling were conducted in the fall of 1999 to assess the kokanee population. We estimated the abundance of each age class of kokanee as: 6.023 million age-0 (wild and hatchery fry), 883,000 age-1, 409,000 age-2, 579,000 age-3, 861,000 age-4, and 87,000 age-5. Wild fry abundance was estimated at 2.57 million fish. These originated from 43.1 million eggs spawned in the wild during the fall of 1998. The survival from wild spawned eggs to wild fry was, therefore, 6.0%. This was lower than the 9.6% survival rate calculated last year but was much higher than the 1.4% calculated in 1995 prior to changing lake levels. To date, years of higher winter lake elevations have out-performed years of full drawdown.

Based on data collected during trawl sampling, the total number of eggs laid in the lake in the fall of 1999 was 74.8 million. Mean fecundity per female was 379 eggs. Hatchery personnel collected 22.4 million eggs, leaving 52.4 million eggs to be laid by wild fish in tributary streams and along the lake shoreline. These eggs will be used to assess wild kokanee survival during 2000.

Peak counts of spawning kokanee were 3,500 fish on the shoreline and 16,400 fish in tributary streams. This represents only a fraction of the total kokanee spawning population.

Opossum shrimp *Mysis relicta* increased slightly in the southern two sections of the lake but decreased in the northern end. Immature and mature shrimp (excluding young-of-the-year shrimp) densities averaged 302 shrimp/m^2, down from 426 shrimp/m^2 the previous year. The relatively stable shrimp population was not thought to affect the outcome of the lake level testing.

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INTRODUCTION

The decline of the kokanee *Oncorhynchus nerka* population in Lake Pend Oreille has been largely attributed to the current operation of Albeni Falls Dam (Maiolie and Elam 1993; Paragamian and Ellis 1994). Historical population trends and harvest data indicated winter pool elevation affected kokanee abundance and harvest. Drawdowns of the lake below the elevation needed for flood control exposed most of the shoreline gravel that limited kokanee spawning. In an attempt to recover the kokanee population, the Idaho Department of Fish and Game (IDFG) proposed that the lake be drawn down only to a winter lake level of 626.7 m (2,056 ft) above mean sea level, approximately 1.5 m above the minimum level used from 1966 to 1995. Gravel surveys conducted in 1994 determined this would increase the amount of suitable kokanee spawning gravel by 560 percent (Fredericks et al. 1995).

The Northwest Power Planning Council (NWPPC) directed the US Army Corps of Engineers to change the winter elevation of Lake Pend Oreille beginning in the winter of 1996. The lake was to be kept above an elevation of 626.4 m (2,055 ft, 1.2 m higher) for three winters. The NWPPC also directed the Bonneville Power Administration (BPA) to fund IDFG to investigate the effect of lake level changes on kokanee production; possible movements of shoreline gravel and sediment; a lake energy budget including zooplankton, predation levels and predator abundance, Opossum shrimp *Mysis relicta* and food availability for fry and adult kokanee; changes in the abundance of warm water fish species; concerns about Eurasian water milfoil, and effects on wildlife and waterfowl. These studies were to be conducted between 1996 and 2001. After this time, fishery managers were to meet and discuss options for managing the lake levels on a long-term basis. This report covers the third year of findings on this study and covers our work on lake level changes, shrimp monitoring, spawning gravel quality, and changes in riparian vegetation. Conclusions on the effect of lake levels would be premature at this point.

OBJECTIVE

To return kokanee harvest to 750,000 fish annually with a mean length of 250 mm. This will be possible once the abundance of harvestable-sized kokanee reaches 3.75 million fish.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 1). It is the state's largest lake and has a surface area of 38,300 ha, a mean depth of 164 m, and a maximum depth of 351 m. Summer pool elevation of Lake Pend Oreille is 628.7 m. Pelagic habitat used by kokanee is considered to be 22,546 ha (Figure 1) (Bowler 1978). The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) averaged approximately 9 C in the upper 45 m (Rieman 1977; Bowles et al. 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m during summer (July-September) followed by reduced lake levels of 625.1 m during fall and winter (typical dam operation between 1966 and 1996). During the first three winters of this study, the winter lake level was held above 626.4 m. A drawdown to 625.1 m was scheduled for the winter of 1999-2000, but due to legal action, the lake level was held at 625.7 m (Figure 2).

A wide diversity of fish species was present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s from Flathead Lake and were well established by the 1940s. Other game fish include: Gerrard rainbow trout *Oncorhynchus mykiss,* bull trout *Salvelinus confluentus*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus clupeaformis*, mountain whitefish *Prosopium williamsoni*, and lake trout *Salvelinus namaycush,* in addition to several other cool and warm water species.

METHODS

Hydroacoustics

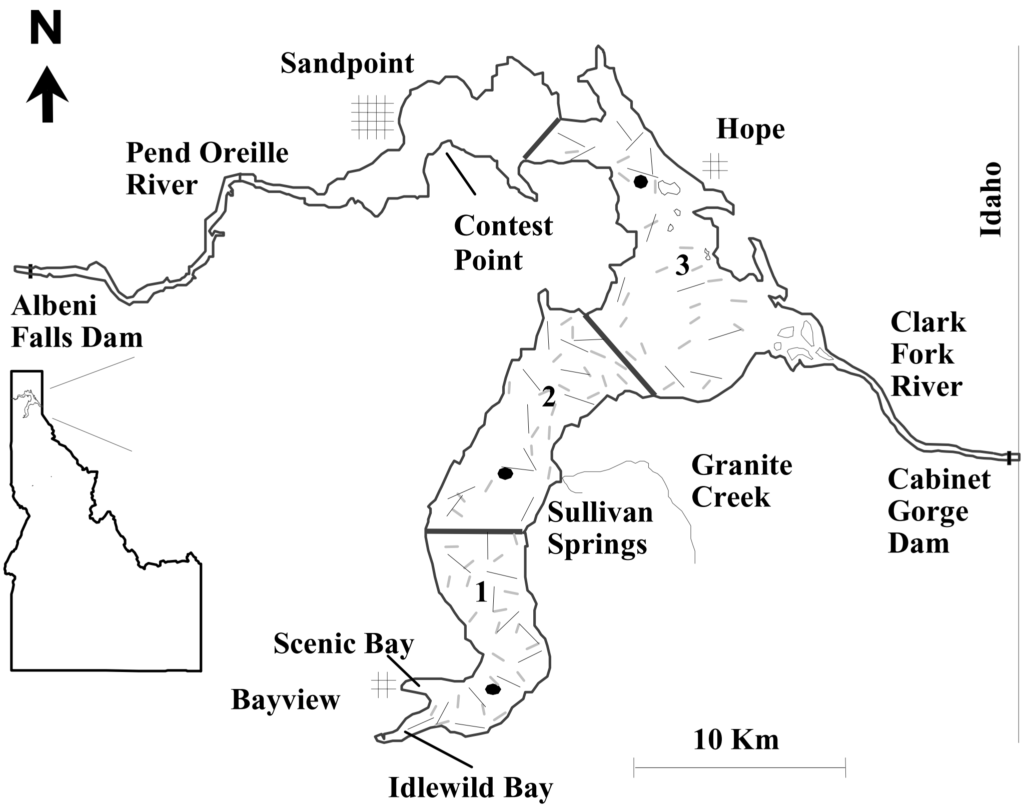
We conducted hydroacoustic surveys on Lake Pend Oreille at night between August 23 and 25, 1999. Twenty transect locations were randomly chosen in each of three lake sections for a total of 60 transects. We also randomly selected a compass bearing for the direction of each transect (Figure 1).

At each location, a 10-minute hydroacoustic survey was conducted using a Simrad EY500 portable scientific echo sounder. Boat speed was approximately 1.5 m/s. (Boat speed did not affect our calculations of fish density.) The echo sounder was set to ping at 1.0 s intervals. Calibration of the echo sounder was checked using a copper calibration sphere before the start of surveys and gains adjusted to achieve the correct target strengths. The echo sounder was annually calibrated to correct for signal attenuation to the sides of the acoustic axis using Simrad's Lobe program. We analyzed the survey information using Simrad EP500 software version 5.2.

We used the mean target strength of 496 fish that were "trace tracked" to separate age classes of kokanee. To be considered a fish in the trace track, it had to be detected (pinged) at least twice, not move more than 30 cm vertically between detections, and not be missed by more than 1 ping during the tracking. A bar graph of target strength versus frequency was then drawn. We used the low points on the graph to define the breaks between age classes of fish.

All pelagic "targets" between –45 dB and –33 dB were considered kokanee from ages 1 to 5. To split these fish into abundance estimates for each age class, the hydroacoustic estimate of abundance for each lake section was multiplied by the proportion that were ages 1 through 5 in the trawl catch within that section.

Targets between –60 and –45 dB were considered kokanee fry. To estimate abundance of hatchery and wild fry, we took the total estimate of fry in each section of the lake based on hydroacoustics and multiplied it by the proportion of each type of fry collected in the trawl samples for that section. (Fry in the trawl samples had their otoliths sent to Washington Department of Fisheries and Wildlife to see if they had the cold-brand mark of a hatchery fish.) A second method was also used where fry abundance based on hydroacoustics was multiplied by the proportion of each type of fry collected in the fry net samples in each section of the lake. Section totals were summed to get lake-wide abundance estimates of hatchery and wild fry.



Section	Area (hectares)
1	6386
2	7776
3	8384

● - Limnology stations

/ - Hydroacoustic transects

/ - Trawl transects

Figure 1. Map of Lake Pend Oreille, Idaho showing prominent landmarks, the three sections used for estimating kokanee and shrimp abundance, transect locations, and limnology stations. Inserted table depicts the area of kokanee habitat in each section.

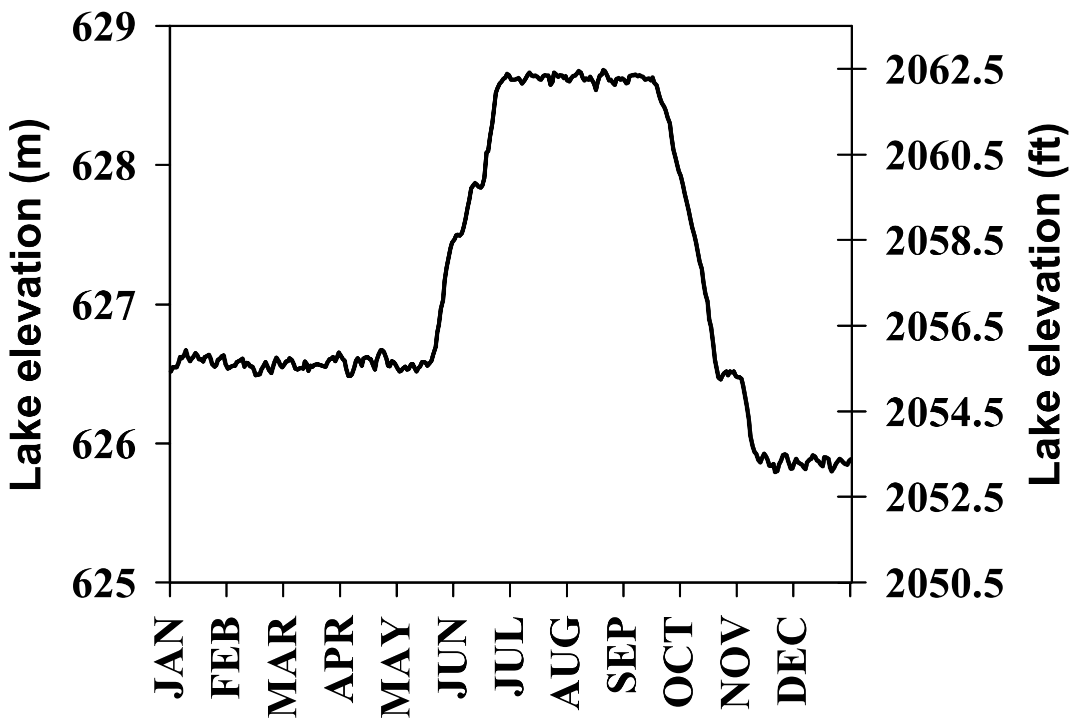


Figure 2. Surface elevation of Lake Pend Oreille, Idaho 1999. Note that the minimum pool elevation was reduced in November 1999.

Midwater Trawling

We conducted standardized midwater trawling in Lake Pend Oreille from September 7 to 10, 1999. These dates were during the dark phase of the moon, which optimized the capture efficiency of the trawl (Bowler et al. 1979). The lake was divided into three sections (Figure 1), and a stratified random sampling scheme was used to estimate kokanee abundance and density.

Twelve transects were randomly selected within each section, and one haul was made along each transect. We located each trawl site using the Global Positioning System (GPS).

Rieman (1992) described the midwater trawl equipment and sampling procedures. The net was 13.7 m long with a 3 m x 3 m mouth, which was held open by 3 m long, vertical spreader bars. Mesh sizes (stretch measure) graduated from 29, 25, 19, and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.5 m/s by an 8.8 m boat. We determined the vertical distribution of kokanee by using a Furuno Model FCV-582 depth sounder with a 10° transom mounted transducer. A step-wise oblique tow was conducted along each transect, which sampled the entire vertical distribution of kokanee. Fish from each trawl sample were counted and placed on ice until morning when they were transferred to a freezer. Length and weight of individual kokanee was recorded, and all fish over 170 mm were checked for maturity. Scales were taken from 10 fish in each 10 mm size interval for aging. Otoliths were removed from age-0, age-1, and age-2 kokanee. One hundred otoliths from age-0 and another 105 otoliths for age-1 and -2 kokanee were sent to Washington Department of Fisheries and Wildlife for analysis.

Fish numbers/transect (haul) were divided by transect volume and the age-specific and total number of kokanee for each stratum and lake total were calculated using standard expansion formulas for stratified sampling designs (Scheaffer et al. 1979). The area of each section was calculated for the 91.5 m contour; however, the northern section was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978. Ninety percent confidence intervals were calculated on the kokanee abundance estimates (Scheaffer et al. 1979).

Potential egg deposition (PED) was calculated by determining the percent maturity in each 10 mm length group of age-3, age-4, and age-5 kokanee in the trawl catch (by dissection). Percent maturity in each 10 mm length group was then multiplied by the population estimate for that particular length group. The maturity estimate for each length group was summed and divided by two to obtain the number of mature females. Number of mature females in the lake was then multiplied by the mean fecundity seen at the Granite Creek spawning station to estimate potential egg deposition. We then subtracted the number of eggs collected by hatchery personnel at the Cabinet Gorge Hatchery and Granite Creek egg-take stations to determine the number of eggs spawned by wild fish (wild PED).

Fry Netting

For the first time in Lake Pend Oreille, we used a small mesh net to collect samples of kokanee fry. The net was 1.27 m by 1.57 m across the mouth (2 m^2) and was 5.5 m long. Bar mesh size for the net was 0.8 mm by 1.6 mm. The sampling bucket on the cod end of the net contained panels of 1 mm mesh. Sampling was conducted on September 1 to 3, 1999. We towed the net at five randomly chosen sites in each of the lake's three sections (total 15 tows). Boat speed was 1.45 m/s. Oblique tows were made through the layer of kokanee seen on the boat's echo sounder. Depths ranged from 13 m to 41 m. The net was towed for 3 min at each "step" (a step corresponded to a 15 m length of cable) until the entire kokanee layer had been sampled.

A Kahlsico digital flow meter model 005WE138 was secured in the net's mouth 1/3 of the way between the net frame and the center of the mouth. However, density of fry was calculated for each net tow based on the distance the net was towed (boat speed x time) times the area of the net mouth. Flow meter readings were not used, since they recorded the distance while the net was lowered and raised. Density estimates were averaged per section and expanded by the area of the section. Estimates of fry within each section were summed to determine a lake-wide population estimate of fry. Total lengths of each fry were rounded down to the nearest whole mm. The proportion of wild and hatchery fry was determined by using data collected from the mid-water trawling. Otoliths from trawl caught fry were sent to Washington Department of Fisheries and Wildlife for analysis. The percent of hatchery and wild fry in each centimeter length group was applied to the fry net samples to determine composition.

Hatchery Fry Marking

All kokanee fry released from the Cabinet Gorge Fish Hatchery in 1997, 1998, and 1999 were marked by "cold branding" their otoliths (Volk et al. 1990). The intent of this marking was to enable researchers to separate hatchery and wild kokanee throughout their lifecycle by noting the dark banding pattern on the otoliths of the hatchery fish.

A total of 8.248 million fry were stocked in 1999. Fry were of two types: 1.121 million early spawning variety from Meadow Creek stock of Kootenai Lake British Columbia, and 7.127 million late spawning kokanee from spawn taken in Lake Pend Oreille.

Cabinet Gorge Fish Hatchery personnel reared and marked all of the kokanee fry. Fry within an individual raceway were from eggs collected within ten days of each other. Thermal treatments were initiated five to ten days after fry entered their respective raceways. In 1999 fry were treated to create unique banding patterns on their otoliths. Fry in 1997 were given five evenly spaced bands by placing them on cool water (5°C) for 24 h and then returning them to normal (10°C) rearing temperatures for 24 h and repeating this five times. Fry in 1998 were marked with five cool water events; however, the number of days between cool water events changed. Between the first and last two cool water events, the fry were returned to normal rearing temperatures for three days. Between the 2^{nd}, 3^{rd}, and 4^{th} bands, only one day of normal temperatures was given.

In 1999 (brood year 1998), fry of Lake Pend Oreille origin received four 24 h cool water events scheduled over nine days with one day between the first two and last two events, and three days between the second and third events. Fry of the early spawning variety were given a unique pattern created by elevating water temperatures for two days followed by two days of ambient water temperatures, repeated four times.

Twenty fry from each raceway were sacrificed to verify the thermal marking. These fry were sent to the Washington Department of Fish and Wildlife, Otolith Laboratory, in Olympia, Washington. Recognizable otolith marks were verified on all thermally treated individuals. All thermally treated individuals exhibited their respective mark patterns.

We sent 205 pairs of kokanee otoliths from the trawl samples to the Washington Department of Fish and Wildlife for analysis. Otoliths were not randomly chosen. Instead we attempted to send approximately 10 pair of otoliths from each 10 mm kokanee size group from 20 mm to 230 mm. Before shipment, we catalogued each fish, recorded total length and weight, and removed, cleaned, and catalogued the sagittal otoliths.

Washington Fish and Wildlife personnel removed one sagitta from each of the 205 vials and oriented it on a glass plate labeled to associate the otolith with the specimen vial. Under a fume hood, otoliths were positioned on a glass plate and surrounded with a preformed rubber mold. Rubber molds were then filled with clear fiberglass resin and warmed in an oven for approximately 1 h for curing. The resulting blocks of resin containing the otoliths were cut into groups of four otoliths per block for sectioning and polishing. Blocks of four otoliths were lapped on a rotating disc of 500 grit carborundum paper until the nucleus of each otolith was clearly visible. The otoliths were then polished using a rotating polishing cloth saturated with one micron deagglomerated alpha alumina and water slurry. After lapping and polishing, the otoliths were examined with a compound microscope at 200 power and/or 400 power magnification. Patterns within the otolith were compared to those on reference samples taken from the hatchery fry during rearing. For accuracy, two independent readers examined each otolith. Differences between the readers were settled by re-examining the otolith.

Spawner Counts and Surveys

We walked standard shoreline areas (Appendix A) and tributaries and counted spawning kokanee to continue this data set. All areas surveyed have been documented as historical spawning sites (Jeppson 1960). Nine shoreline areas were surveyed once a week for three straight weeks starting with the third week in November 1999. All kokanee, either alive or dead, were counted. The highest count at each site was reported.

Eight tributary streams were surveyed by walking upstream from the mouth to the highest point utilized by kokanee during the same period as shoreline counts. Trestle Creek, which supports a run of early spawning kokanee, was also surveyed on September 21, 1999 for spawners.

Kokanee Redd Mapping

At the end of the 1999 kokanee spawning season, we surveyed the entire shoreline to determine locations used by spawning kokanee. The lake's 145 km of shoreline was broken down into 14 sections, beginning and ending at prominent landmarks. Using a 24 ft boat and wearing polarized sunglasses, three researchers cruised the shoreline measuring all visible redds. Redd depth and area were measured using a 5 m long wooden pole marked for depth. At the end of the pole was a one meter long rod to measure redd surface area. If redds were deeper than 5 m, a 60 m measuring tape, with a lead weight attached, was used to measure depth. The redd depth surveys were conducted between December 16, 1999 and January 18, 2000. We tabulated the depth and area of redds within each section so they could be separately compared to future surveys.

Shrimp Abundance

Opossum shrimp were sampled on June 14 to 16, 1999 to estimate abundance and determine whether changes in shrimp abundance could influence the outcome of the lake level experiment. All sampling occurred at night during the dark phase of the moon. Eight sampling sites were randomly located in each of three sections of the lake (Figure 1). We used GPS coordinates to locate each sampling site.

We collected shrimp using a hoop net that was 1 m in diameter and equipped with a flow meter. Net mesh and cod-end bucket mesh measured 1 mm and 0.5 mm, respectively. We lowered the net to a depth of 45.7 m (150 ft) and raised it to the surface at a rate of 0.5 m/s using an electric winch. Shrimp were immediately placed in denatured ethanol for preservation.

We also collected shrimp with a Miller sampler that had a 104 mm diameter opening (.00849 m^2) and 500 µm mesh. Sampler was lowered to 45.7 m and towed at 1.7 m/s. It was then raised 3 m at 10 s intervals until it reached the surface. The horizontal distance that the sampler was towed was measured by placing a General Oceanics Incorporated flow meter over the side of the boat when the transect started. Samples with the Miller sampler were collected concurrently with the vertical net tows at 12 sites by using a second boat. Densities of shrimp collected by the two methods were compared by linear regression analysis so that a conversion equation could be developed.

Mysids were measured from the tip of the rostrum to the end of the telson, excluding setae, and classified into five categories according to sex characteristics: young of year, immature males and females, and mature males and females (Gregg 1976; Pennak 1978).

Kokanee Egg Incubation Studies

We began a study to monitor the survival of kokanee eggs incubating on the lake's shorelines in December of 1998. Green kokanee eggs were obtained from the Sullivan Springs egg take station on Granite Creek, and transported by boat to the study locations immediately after fertilization. Eggs were allowed to water harden for one hour before being placed into egg baskets. One hundred kokanee eggs were placed into each of 45 plastic mesh baskets. Substrate samples were collected from the spot where each basket was buried, and a portion of the sample was retained for lab analysis. The remainder of the sample was placed inside the egg basket at the same time as the eggs, in such a fashion as to mix the eggs throughout the basket. We attempted to eliminate any concentrations of eggs, or voids in the substrate, which might bias survival rates of the eggs inside the baskets. These baskets were tagged with a strip of colored surveyors ribbon, marked with sample identification numbers, and buried in the substrate at three locations around the lake. The three locations were: the north shoreline near Hope, the gravel beach below Bernard Peak, and the shoreline in front of Hudson's Bay Marina in Scenic Bay. These sites were chosen because they were currently or historically used by kokanee for spawning. At each location, five baskets were buried under about 5 cm of gravel at water depths from 2 to 7 m, five were placed at depths between 0.8 and 1.5 m, and five controls were placed at depths of 0.8 to 1.0 m in an artificial redd made of 100% cleaned, 15-20 mm gravel. These controls were located in the gravel band formed above the previous winter lake level, which we thought would represent the best possible conditions for egg survival. One third of a meter of the marking ribbon was left exposed above the gravel to enable researchers to relocate each site. We recovered test and control baskets at each site monthly. One basket of each group was sampled from each site in January, February, and March, with two baskets of each group left to be collected in April. The numbers of live eggs, dead eggs, and sac fry were counted to determine percent survival rates. The intent was to demonstrate how depth, and its associated gravel quality, influence egg survival.

Limnology

We measured water temperature, dissolved oxygen, and water clarity (Secchi transparency) monthly from April through December 1999. Data were collected at three standardized stations that represented the southern, middle, and northern sections of the lake (Figure 1). Sample dates were approximately the middle of each month. We used a Yellow Springs Instrument Model 57 to measure temperature and dissolved oxygen from the surface to a depth of 59 m. The meter was calibrated before each survey using the “water saturated air” method suggested by the manufacturer. Water clarity was monitored at each station using a 20 cm diameter Secchi disc during each survey.

Gravel Sampling

Five areas of shoreline were sampled in 1999 to determine if potential spawning gravel is increasing in silt content or becoming unusable to kokanee spawners. Areas surveyed included the lake's shoreline at a site in Garfield Bay, at Trestle Creek, just north of the mouth of North Gold Creek, at Hope, and at Ellisport Bay. Each of these sites was surveyed in 1992 (Maiolie and Elam 1993), and 1998 (Maiolie et al. 2000). Each site was a historical location for kokanee spawning (Jeppson 1960).

Sampling was conducted from July 26 to August 17, 1999. At this time the lake was at its summer full pool level, and all gravel samples were collected while scuba diving. We tied a rope to the shoreline at each transect location and stretched it out into the lake perpendicular to the shore. Two scuba divers swam parallel to the rope and visually identified bands of similar substrate composition. Flagging was tied to the rope to mark the distances to the top and bottom of the substrate bands. Two random samples of substrate were collected from each substrate band. Samples were collected by scooping approximately two liters of substrate into a container and sealing it underwater to eliminate the loss of fine material during transport to the surface.

At Garfield Bay a different method of collection was used. We collected a sample every 1.2 m along the transect that extended from the 625.5 m elevation (2052.3 feet) to the summer pool level of 628.6 m (2,062.3 feet). From elevation 624.8 m (2050) to 625.5 m (2052.3 feet) the substrate composition was visually estimated because the cobble rock substrate was too large to fit in the sample container.

Each sample was individually bagged, labeled, and oven-dried. We then screened each substrate sample through soil sieves of the following sizes: 63.5 mm, 31.75 mm, 16.00 mm, 9.50 mm, 6.35 mm, 2.00 mm, and 0.84 mm. The substrate retained on each screen, and the substrate that fell through the finest screen, was then weighed and calculated as a percent of the weight of the total sample. We defined "cobble" as substrates that were 31.75 mm and larger, "gravel" as substrates between 31.75 and 6.35 mm, and "fines" as the substrate smaller than 6.35 mm.

Riparian Areas

A photographic record of shoreline vegetation was collected from nine standardized locations around Lake Pend Oreille. Locations included the shoreline at: Farragut State Park, Leiberg Point, Idlewild Bay, Bernard Beach near Echo Bay, Sand Creek, Denton Slough, Sandpoint, the mouth of Trestle Creek, and the west channel of Trestle Creek. Photographs were compared to those at the same locations taken early in the study to determine whether there have been major changes to riparian vegetation due to the changes in winter lake levels.

RESULTS

Hydroacoustics

Mean target strengths of "trace tracked" kokanee showed a clear separation between age-0 kokanee and larger fish at the -45 dB level (Figure 3). This corresponded to a fish length of 100 mm (Love 1971). We therefore separated kokanee fry from older kokanee at -45 dB. No separation between older age classes (age-1 to -5) could be defined based on target strengths.

We estimated the lake contained 8.842 million (±10%) kokanee on August 23-25, 1999 based on hydroacoustic surveys. This included 6.023 million fry (±9%) and 2.819 million (±18%) kokanee from age-1 to -5. We separated the hydroacoustic estimate of age-1 to -5 fish based on the percent frequency of kokanee age classes in trawl samples for each section of the lake (Table 1). The lake contained 6.023 million age-0 kokanee, 883,000 age-1 kokanee, 409,000 age-2 kokanee, 579,000 age-3 kokanee, 861,000 age-4 kokanee, and 87,000 age-5 kokanee. The percentage of each age class that was wild and hatchery (based on otolith analysis of trawl caught kokanee) was used to divide the age classes into individual groups. Therefore, based on hydroacoustics, we estimated the lake contained 390,000 wild age-1 kokanee, 493,000 hatchery produced age-1 kokanee, 183,000 wild age-2 kokanee, 226,000 hatchery produced age-2 kokanee, 579,000 age-3 kokanee, 861,000 age-4 kokanee, and 87,000 age-5 kokanee (Table 2).

The hydroacoustic estimate of fry was likewise separated into different groups based on their percent frequency in trawl samples. Wild fry comprised 65% of the fry in the southern section, 44% in the middle section, and 31% in the northern section (Table 3). We estimated the lake contained 2.573 million wild kokanee fry, 3.154 million fry of the late spawning strain, and 0.296 million fry of the early spawning strain (Table 2). The 2.573 million wild fry came from 43.181 million wild-spawned eggs that were laid in the lake and in tributaries in 1998. Survival of naturally deposited eggs to wild fry was therefore 6.0% based on hydroacoustic with the trawl breakdown of composition (Table 3).

Additionally, the 6.023 million fry estimated by hydroacoustics could also be divided into the percentages of wild and hatchery fish collected by the fry net. This net has finer mesh than the trawl net so that the smaller wild fry could not go through the netting. The percentages of wild fry in this net were 81% in the southern section, 78% in the middle section, and 48% in the northern section. The acoustic estimate for each section was 1.234 million, 2.128 million, and 2.661 million. Multiplying the percentage by the abundance estimates produced an estimate of 3.937 million wild kokanee fry in the lake. Wild egg deposition the previous year was 43.181 million eggs. This yielded a wild egg to wild fry survival rate of 9.1% based on hydroacoustics with the fry net breakdown of composition.

Age-1 kokanee from wild origin in mid-water trawl samples made up 24% of the age-1 kokanee in the southern end of the lake, 26% in the middle section of the lake, and 47% in the northern end of the lake. Multiplying the percent by the number of age-1 kokanee in the hydroacoustic estimate, by section, produced an estimate of 390,000 wild and 493,000 hatchery age-1 kokanee (Table 2). These fish came from 1.026 million wild fry and 2.682 million hatchery fry last year. The annual percent survival of wild kokanee from age-0 to age-1 was 38%. The annual percent survival of hatchery kokanee for the same age group was 18%.

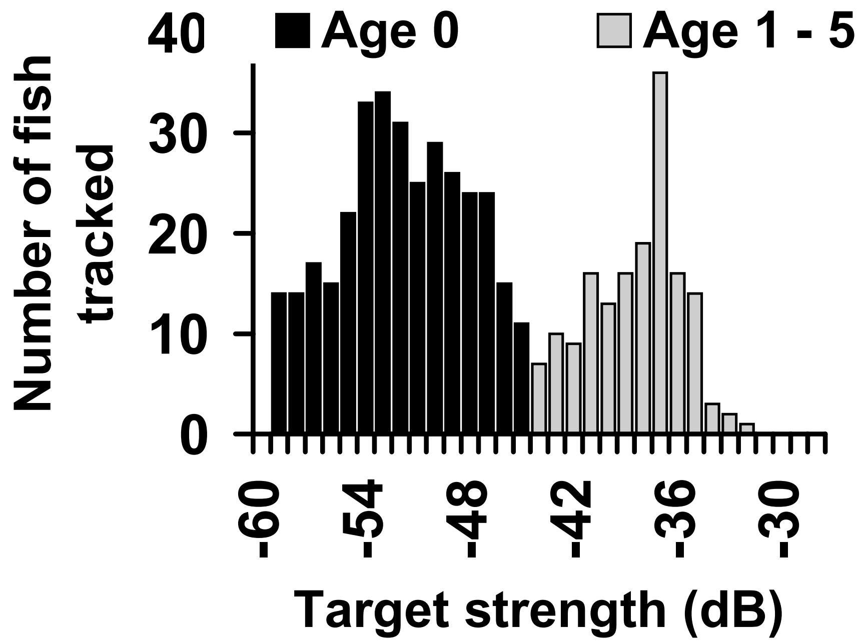


Figure 3. Target strengths of 496 kokanee recorded during hydroacoustic surveys on Lake Pend Oreille, Idaho during August 1999.

Table 1. Hydroacoustic population estimates, partitioned into age-classes by the percentage in the mid-water trawl catch, for Lake Pend Oreille, Idaho, 1999.

	Age-0	**Age-1**[a]	**Age-2**[a]	**Age-3**[a]	**Age-4**[a]	**Age-5**[a]	**Total Pop.**
Section 1							
Hydro. Est.	1,234,414	64,940	110,301	193,716	360,271	32,622	1,996,264
% of age-1-5 total in each age-class[a]		8.52%	14.48%	25.43%	47.29%	4.28%	
Section 2							
Hydro. Est.	2,127,902	36,642	43,851	66,653	84,073	9,059	2,368,180
% of age-1-5 total in each age-class[a]		15.25%	18.25%	27.74%	34.99%	3.77%	
Section 3							
Hydro. Est.	2,661,082	781,050	254,658	318,232	416,681	45,773	4,477,476
% of age-1-5 total in each age-class[a]		43.0%	14.02%	17.52%	22.94%	2.52%	
Age Class Totals	6,023,398	882,632	408,810	578,601	861,025	87,454	8,841,920
% of total pop.[a]	68.12%	9.98%	4.62%	6.55%	9.74%	0.99%	

[a] Ages 1-5 based on % breakdown of trawl catch per section.

Hydroacoustic estimates of the abundance of age-2 kokanee were also divided by the percent wild and hatchery kokanee in each section. Wild kokanee comprised 35%, 38%, and 50% of the age-2 kokanee in the southern, middle, and northern sections of the lake. We estimated the lake contained 183,000 wild age-2 kokanee and 226,000 hatchery age-2 kokanee (Table 2). Annual survival rate of kokanee from age-1 to age-2 was 13% for the wild fish and 28% for the hatchery fish.

None of the age-3 or -4 kokanee had temperature marks on their otoliths in 1999. Therefore, no differentiation between wild and hatchery fish could be made. Annual survival rates based on hydroacoustics were 71% for age-2 to -3, and 49% for age-3 to -4.

Table 2. Kokanee population estimates in Lake Pend Oreille, Idaho based on hydroacoustic surveys. Hatchery and wild fish were differentiated by otolith analysis or size frequency distribution for fry in 1995. Numbers are in millions.

Year	Age-0			Age-1			Age-2			Age-3	Age-4	Age-5
	Wild	Hatch[a] Late	Hatch[b] Early	Wild	Hatch	Undifferen-tiated	Wild	Hatch	Undifferen-tiated			
1999	2.573	3.154	0.296	0.390	0.493	-	0.183	0.226	-	0.579	0.861	0.087
1998	1.026	2.682	-	1.441	0.800	-	-	-	0.821	1.745	0.220	-
1997	2.590	3.496	-	-	-	2.905	-	-	1.857	0.863	0.115	-
1996	2.058	3.296	-	-	-	3.662	-	-	3.443	0.747	0.490	-
1995	3.173	4.107	-	-	-	3.418	-	-	2.082	1.120	0.248	-

[a] Hatch Late = hatchery kokanee of late spawning strain.
[b] Hatch Early = hatchery kokanee of early spawning strain.

Table 3. Hydroacoustic estimates of kokanee fry partitioned into wild fry abundance based on the percentage of wild fry in the mid-water trawl catch for Lake Pend Oreille, Idaho, during August 1999.

Lake Section	Hydroacoustic Fry Estimate	% Wild Fry in Trawl	Wild Fry Estimate by Hydroacoustics
Section 1	1,234,414	65.22 %	805,085
Section 2	2,127,902	44.16 %	939,681
Section 3	2,661,081	31.13 %	828,395
Whole lake total	6,023,397		2,573,162

Midwater Trawling

In 1999, we estimated total kokanee abundance at 4.709 million fish (Table 4). Kokanee fry abundance was estimated at 3.814 million (±42%, 90% confidence interval). We estimated the lake also contained 233,000 age-1 kokanee (±64%), 140,000 age-2 kokanee (±28%), 204,000 age-3 kokanee (±27%), 288,000 age-4 kokanee (±28%) and 30,000 age-5 kokanee (±36%) (Table 4). Total standing stock for kokanee was 3.87 kg/ha. The density of age-4 and -5 kokanee was 14 fish/ha.

Table 4. Kokanee population statistics based on trawling Lake Pend Oreille, Idaho, September 1999.

	Age						
	0	1	2	3	4	5	Total
Population estimate (millions)	3.8	0.23	0.14	0.20	0.29	.03	4.7
+/- 90% CI	42%	64%	28%	27%	28%	36%	
Density (fish/ha)	169.2	10.4	6.2	9.1	12.8	1.3	209
Mean weight (g)	2.6	29.7	70.9	95.6	128.9	137.4	
Standing stock (kg/ha)	0.43	0.31	0.44	0.87	1.65	0.18	3.87
Mean length (mm)	66	152	199	209	244	252	
Length range (mm)	20-129	110-189	160-229	180-249	220-269	230-269	

Kokanee in the trawl catch ranged from 20 mm to 260 mm (Figure 4). Wild kokanee fry were the smallest group of fry with the early spawning strain of hatchery kokanee being the largest. Hatchery kokanee remained larger than wild kokanee in each age group.

We estimated the lake contained 395,000 mature kokanee, of which 50% were assumed to be female. (Dissection of trawl-caught kokanee revealed a sex ratio very close to 1:1.) Fecundity averaged 379 eggs per female kokanee as determined at the Sullivan Springs egg station in 1999. Therefore, potential egg deposition was estimated at 74.799 million eggs. Hatchery crews collected 22.384 million eggs at Sullivan Springs and Cabinet Gorge Fish Hatchery Ladder. This left 52.415 million eggs to be naturally spawned on the lakeshore and in tributary streams during the fall of 1999.

Survival rates from last year (1998) to this year (1999) based on trawling were: 32% from age-0 to age-1, 16% from age-1 to age-2, 61% from age-2 to age-3, and 40% for age-3 to age-4 fish (Table 5). Survival of eggs laid in 1995 (74.4 million) to age-3 fish in 1999 (0.204 million) was 0.274%.

Average weight of age-3 kokanee in 1999 was 95.6 g. This was higher than most of the past years and may reflect their low density of 9.1 fish/ha (Figure 5).

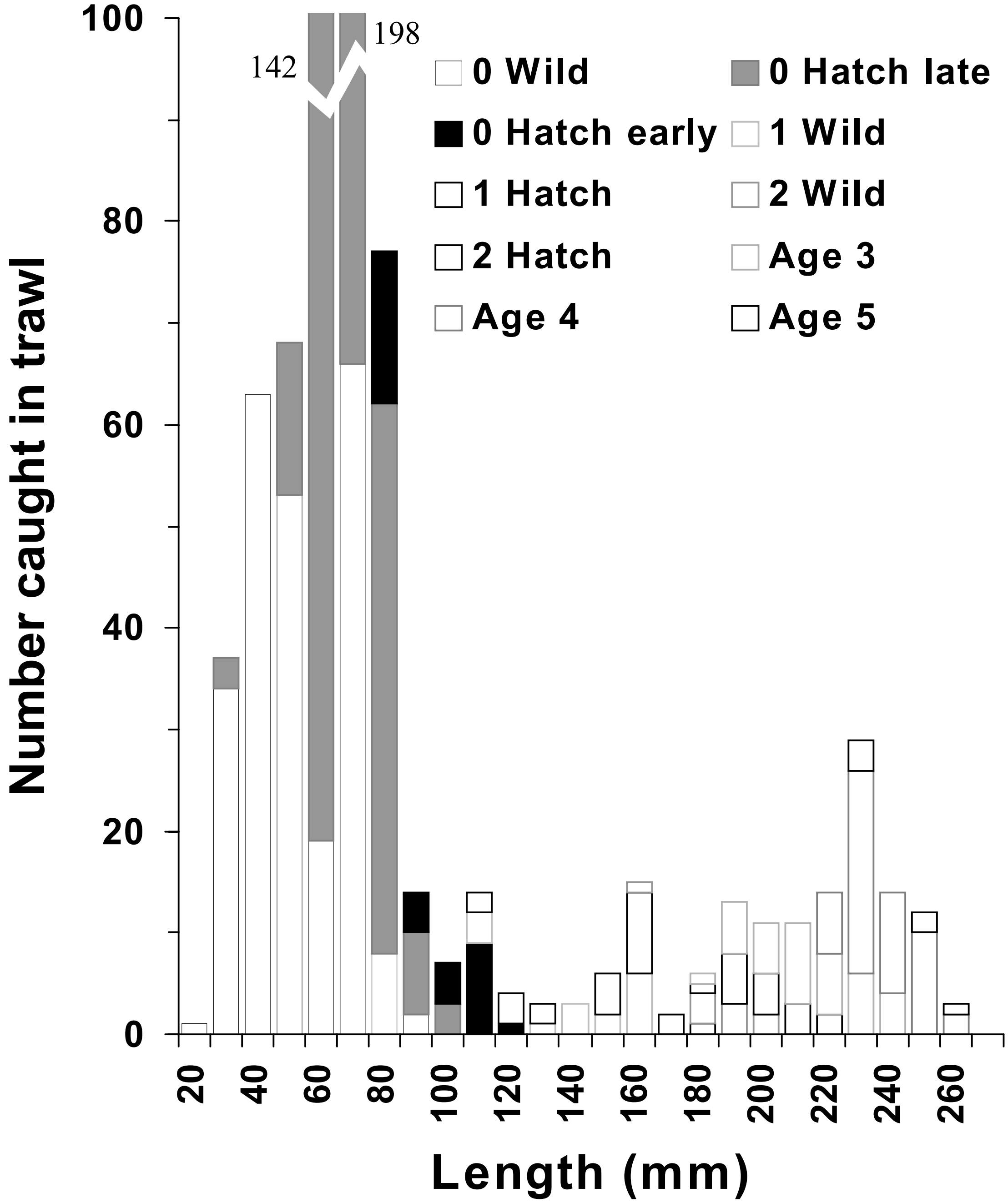


Figure 4. Length-frequency distribution of age-0, -1, and -2 kokanee caught by trawling in Lake Pend Oreille, Idaho, 1999. Age classes were divided into hatchery and wild fish based on otolith marks.

Table 5. Survival rates (%) for kokanee year classes based on trawling data for Lake Pend Oreille, Idaho. Year class is the year eggs were laid.

Year	Age Class				
Class	0 to 1	1 to 2	2 to 3	3 to 4	Eggs to 3
1998					
1997	32				
1996	40	16			
1995	21	29	61		0.27
1994	78	22	92	40	0.30
1993	42	110	12	25	0.17
1992	12	400	44	7	0.40
1991	32	47	106	59	0.80
1990	67	98	76	15	1.55
1989	25	94	256	38	1.70
1988	35	111	63	92	0.94
1987	16	124	53	83	0.66
1986	47	72	27	82	0.48
1985	47	65	88	44	0.37
1984	64	73	45	97	0.43
1983	39	66	63	81	1.26
1982	70	70	43	77	2.49
1981	59	53	[a]		
1980	119	18	[a]		
1979	80	47	[a]		
1978	50	79	[a]		
1977	72	73	[a]		

[a] Unable to calculate survival rate since age-3 and -4 kokanee were not separated prior to 1986.

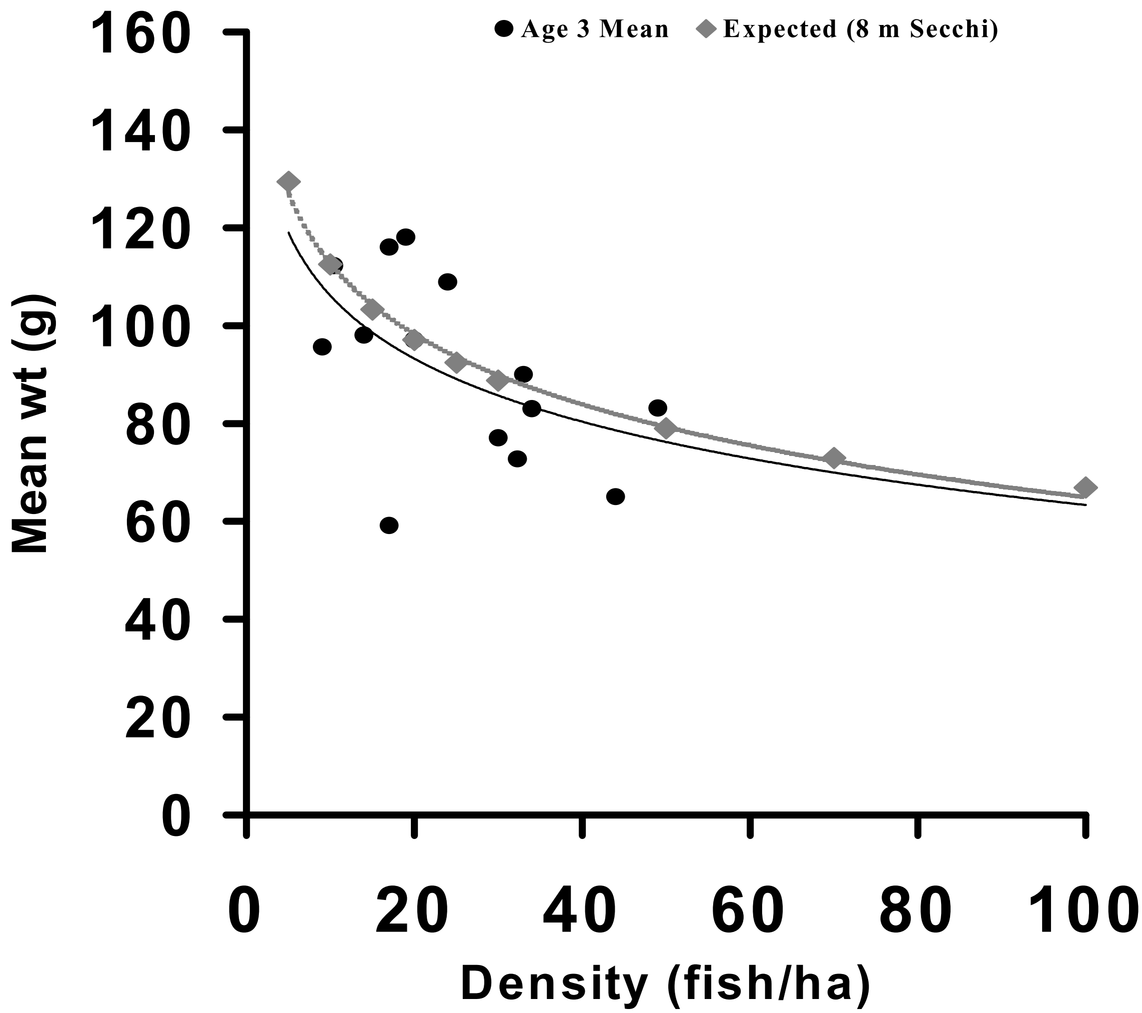


Figure 5. Average weight of age-3 kokanee in Lake Pend Oreille, Idaho. Triangles show expected weights for waters with an 8 m Secchi transparency (Rieman and Meyers, 1990).

Fry Netting

We netted 66 kokanee and one whitefish fry in 15 tows with the fry net. Based on this catch, kokanee fry comprised 98.5% of the small fish collected in the pelagic fish layer. The single whitefish could have been near the surface when the net was being deployed or retrieved; therefore, we still assumed that 100% of the small pelagic targets in the hydroacoustic surveys were kokanee.

Expanding the density estimates of fry yielded population estimates of 1.220 million kokanee fry in the southern section, 1.529 million fry in the middle, 2.085 million fry in the northern section, for a total population estimate of kokanee fry of 4.834 million (Table 6). Multiplying the number of fry caught in each 1 cm length group times the percent of wild fry, the percent of hatchery fry of the late-spawning strain, and the percent of hatchery fry of the early spawning strain, collected in the trawl net yielded estimates of the numbers of fry of each type. The southern section contained 986,000 wild fry, 188,000 hatchery fry of the late spawning strain, and 45,000 hatchery fry of the early spawning strain. The middle section contained 1,192,000 million wild fry, 322,000 hatchery fry of the late spawning strain, and 15,000 hatchery fry of the early spawning strain. The northern section contained 1,011,000 wild fry, 1,016,000 hatchery fry of the late spawning strain, and 59,000 hatchery fry of the early spawning strain. Based on fry netting, the lake contained 3.189 million wild fry, 1.526 million hatchery fry of the late spawning strain, and 120,000 hatchery fry of the early spawning strain. Total fry abundance was therefore 4.834 million ± 29% (90% C.I.) (Table 6). Fry composition was 66% wild, 32% of the late spawning strain, and 2% from the early spawning strain.

Kokanee in the fry net ranged from 26 mm to 101 mm, and the whitefish was 31 mm (Figure 6). Wild fry ranged from 20 mm to 90 mm with modal size of 30 mm. Hatchery-produced kokanee fry of the late spawning strain ranged from 30 mm to 100 mm and had a modal size of 60 mm. Hatchery-produced kokanee fry of the early spawning variety ranged from 80 mm to 100 mm with a modal size of 90 mm (Figure 6).

A higher percentage of the catch in the fry net consisted of kokanee in the smaller size groups than was collected in the trawl net. This was particularly true for kokanee in the 20 to 40 mm size groups, which were more likely to be fry of wild origin (Figure 7). The trawl net caught a higher percentage of fry in the 60 to 80 mm groups.

Table 6. Abundance estimates of kokanee fry in three sections of Lake Pend Oreille, Idaho, September 1999. Estimates were based on the use of a fry net with a 2 m^2 mouth. Confidence interval is 90%.

Section	Wild Fry	Cabinet Gorge Hatchery Fry	Clark Fork Hatchery Fry
Southern	986,000	188,000	45,000
Middle	1,192,000	322,000	15,000
Northern	1,011,000	1,016,000	59,000
Total by type	3,189,000	1,526,000	119,000
Lake total	**4,834,000 ± 29%**		

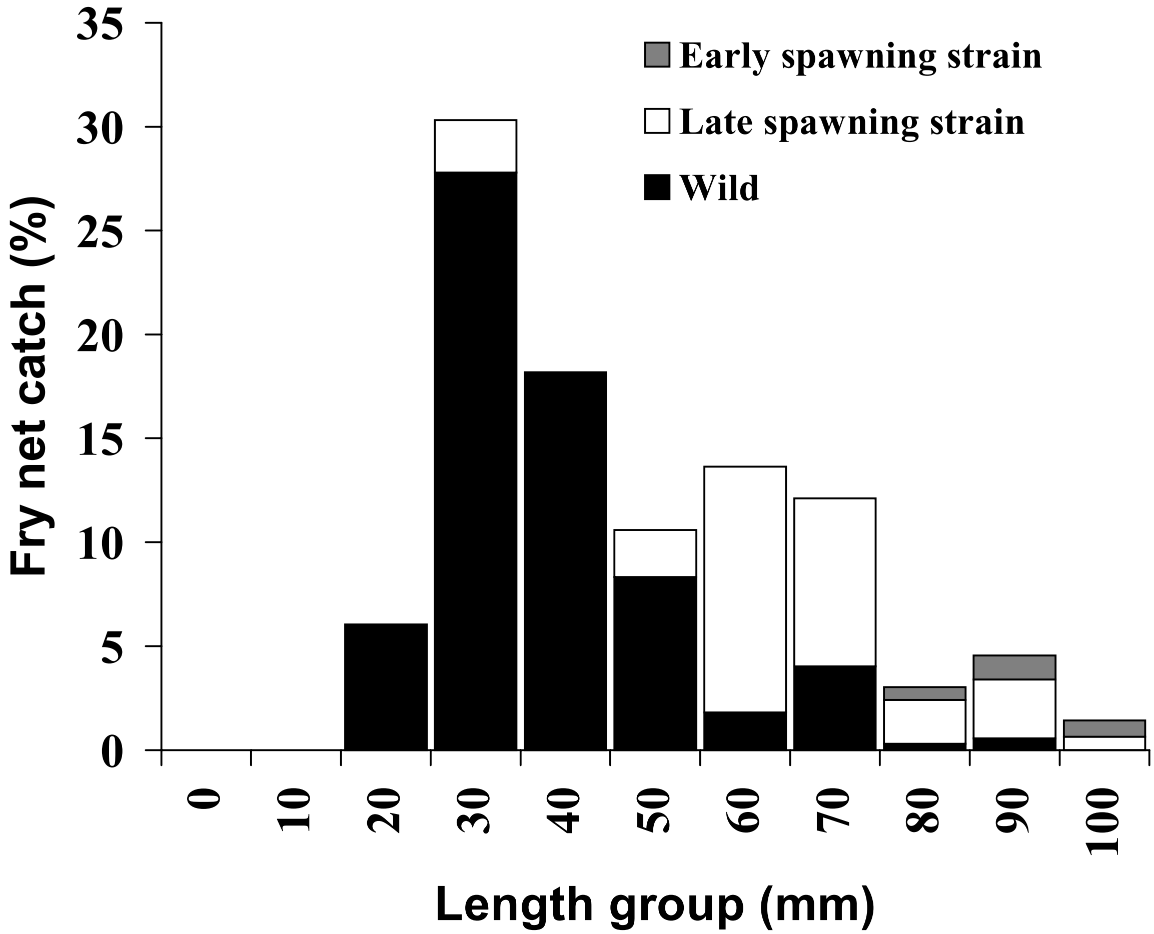


Figure 6. Lengths and frequencies of kokanee fry collected in a small-mesh fry net in Lake Pend Oreille, Idaho, 1999.

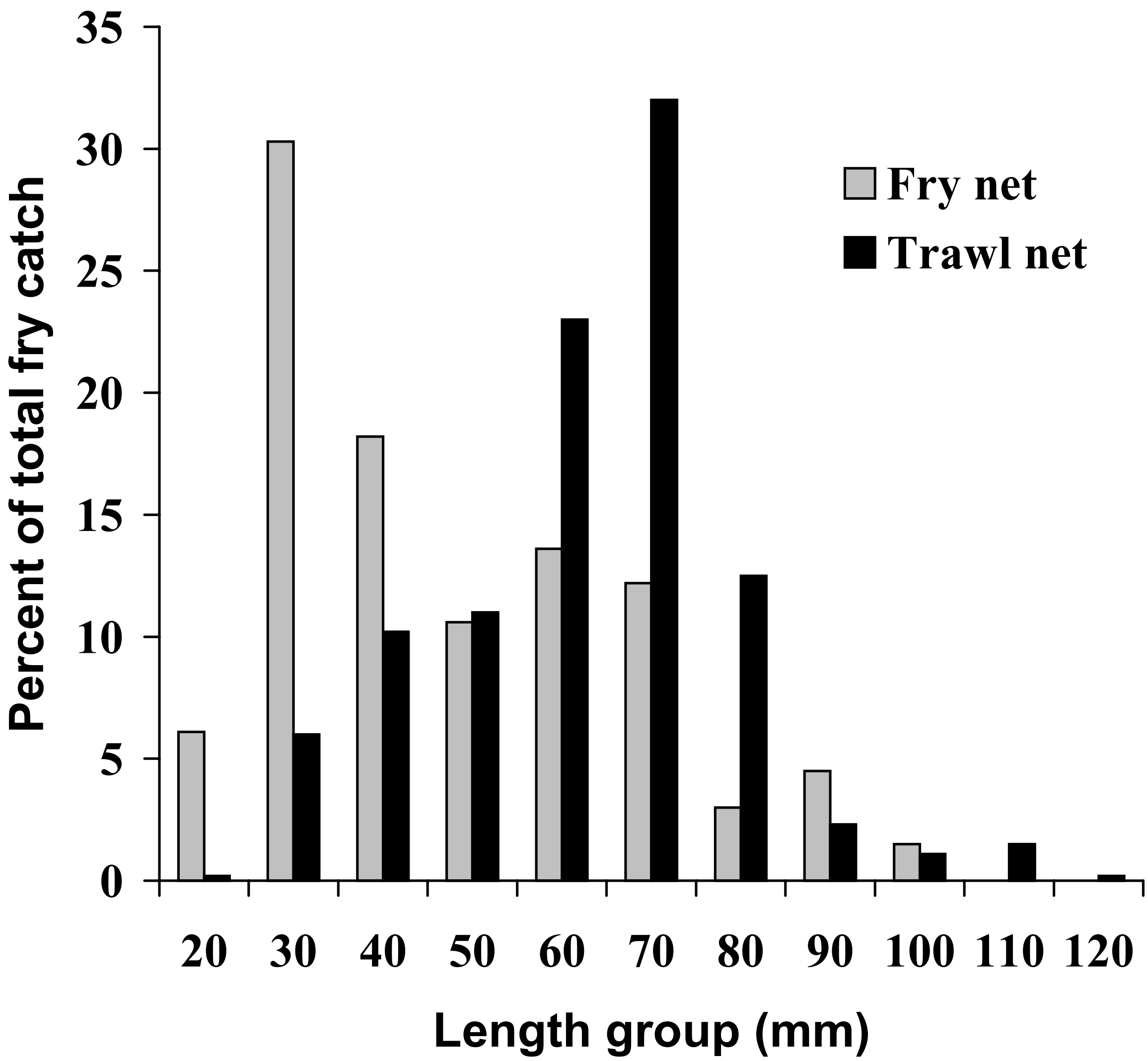


Figure 7. Percent of kokanee fry that were collected in a trawl net and fry net in Lake Pend Oreille, Idaho, 1999.

Otolith Analysis

Of the 205 pairs of otoliths of all age groups sent for analysis from trawl samples, 97 contained marks indicating they were of hatchery origin. Of the kokanee fry sent in, 44 of 100 were from kokanee of hatchery origin. The percentages of wild kokanee fry in each 10 mm size group from 20 mm to 120 mm were: 100%, 92%, 100%, 79%, 13%, 33%, 10%, 13%, 0%, 0%, and 0%, respectively (Figure 8). Percentages of hatchery fry of the late spawning strain in the same size groups were: 0%, 8%, 0%, 21%, 88%, 67%, 70%, 63%, 43%, 0%, and 0%, respectively. Percentages of hatchery fry of the early spawning strain in these size groups were: 0%, 0%, 0%, 0%, 0%, 0%, 20%, 25%, 57%, 63%, and 25%, respectively (Figure 8).

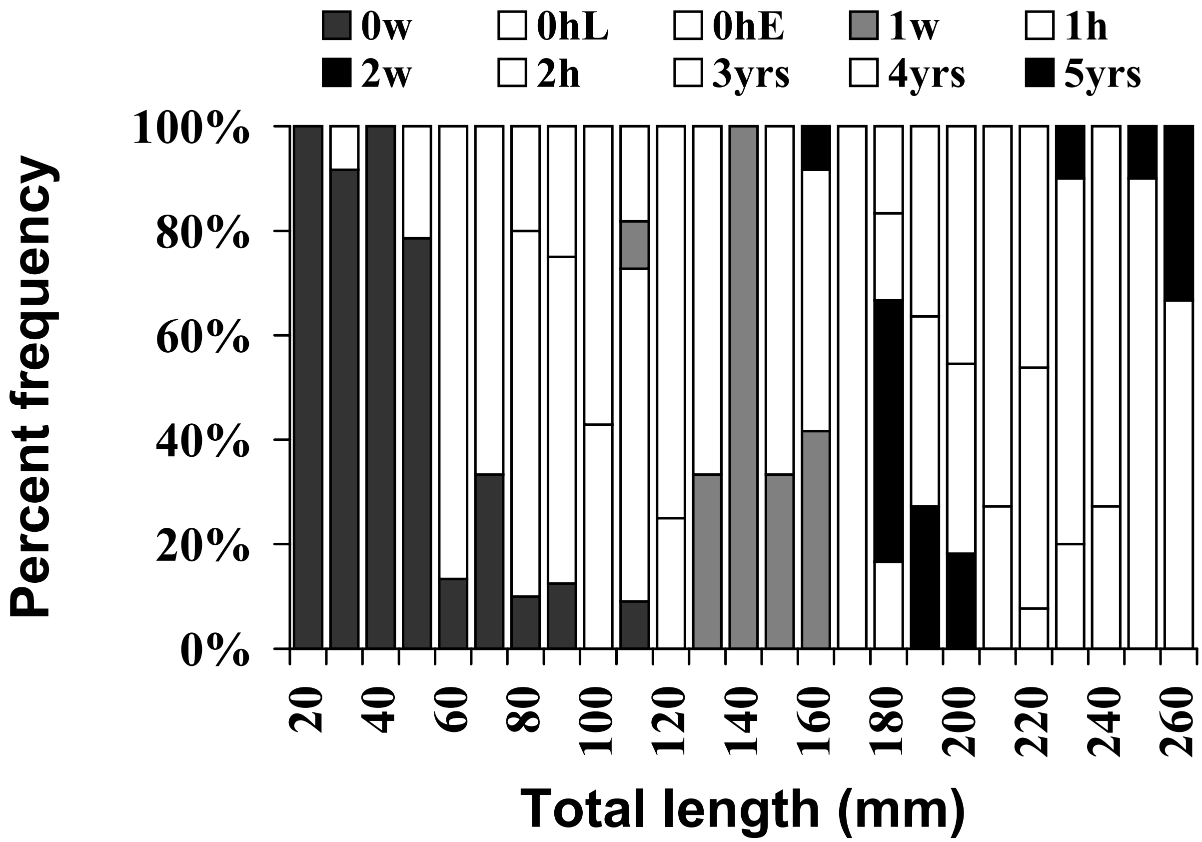


Figure 8. Percent of kokanee in each 10 mm length group as sampled by midwater trawling in Lake Pend Oreille, Idaho. W = Wild-spawned kokanee; H = Kokanee of hatchery origin; L = Late spawning strain; E = Early spawning strain.

Spawner Counts and Surveys

Counts of kokanee spawning along the shoreline in 1999 totaled 3,540 fish, which was above the average of the last 15 years. Nearly all of these fish were seen in Scenic Bay (Table 7). Counts of kokanee spawning in tributary streams totaled 16,446 fish (Table 8). Over half of the tributary spawning occurred in Spring Creek.

Redd Mapping

A total of 3,327 m^2 of redd area was surveyed along the lake's shoreline. Over 70% of the redds, by area, was south of Cape Horn (Figure 9). Scenic Bay contained 1,276 m^2 of kokanee redds, and the section from Idlewild Bay to Gold Creek contained 1,084 m^2 of redds. The area between Gold Creek and Whiskey Rock had the next highest area with 328 m^2 of redds. We found comparatively few redds in the northern part of the lake except near Hope, where 315 m^2 of redds were surveyed. The modal depth of spawning was one meter (Figure 10). Redd depth ranged from 0.15 m to 10.6 m, (however, areas were so small below the 8 m depth that they do not show on Figure 10).

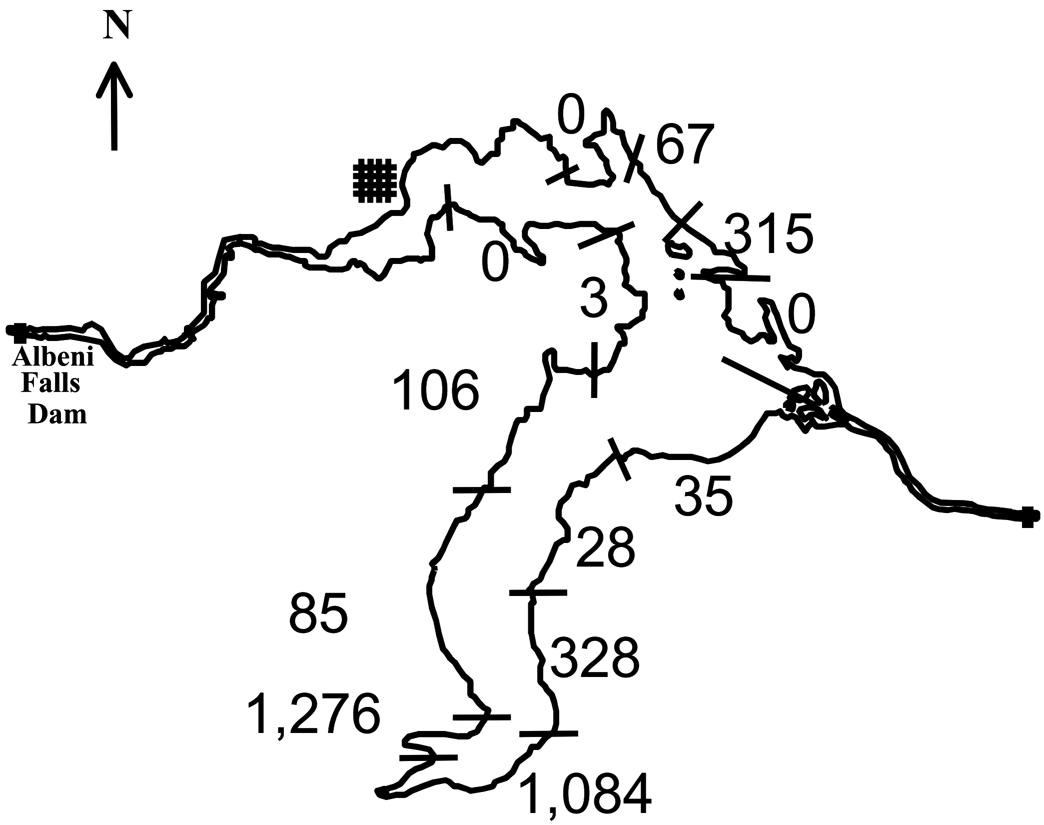


Figure 9. Map of Lake Pend Oreille showing area, in m^2, of kokanee redds surveyed in each of the 14 survey sections.

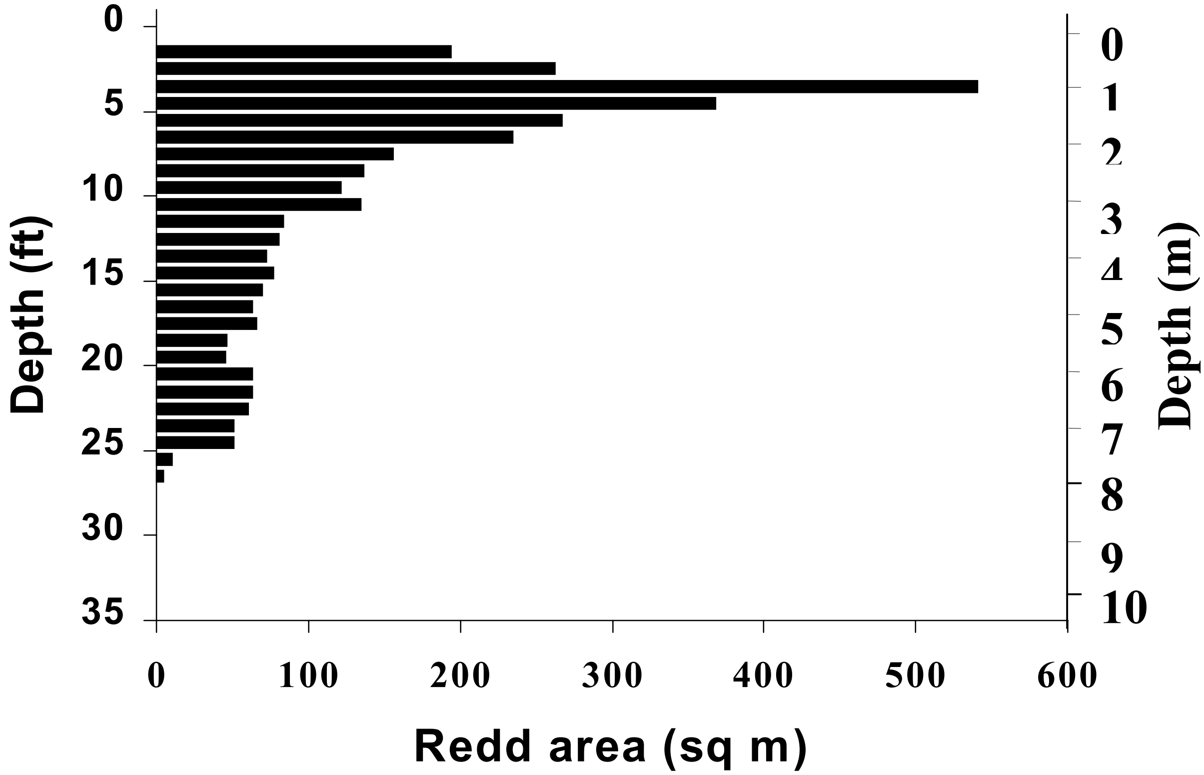


Figure 10. Depth and surface area of kokanee redds surveyed along the shoreline of Lake Pend Oreille.

Table 7. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count.

Year	Scenic Bay	Farragut Ramp	Idlewild Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
1999	2,736	4	7	24	285	209	0	275	0	—	3,540
1998	5,040	2	0	0	22	6	0	34	0	—	5,104
1997	2,509	0	0	0	0	7	2	0	0	—	2,518
1996	42	0	0	4	0	0	0	3	0	—	49
1995	51	0	0	0	0	10	0	13	0	—	74
1994	911	2	0	1	0	114	0	0	0	—	1,028
1992	1,825	0	0	0	0	0	0	34	0	—	1,859
1991	1,530	0	—	0	100	90	0	12	0	—	1,732
1990	2,036	0	—	75	0	80	0	0	0	—	2,191
1989	875	0	—	0	0	0	0	0	0	—	875
1988	2,100	4	—	0	0	2	0	35	0	—	2,141
1987	1,377	0	—	59	0	2	0	0	0	—	1,438
1986	1,720	10	—	127	0	350	0	6	0	—	2,213
1985	2,915	0	—	4	0	2	0	0	0	—	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Table 8. Counts of kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle[a]	Trestle	Total
1999	1,884	434	435	26	2,378	—	—	9,701	5	1,160	423	16,446
1998	4,123	623	86	0	268	—	—	3,688	—	348	578	9,714
1997	0	20	6	0	0	—	—	3	—	615	0	644
1996	0	42	7	0	0	—	—	17	—	753	0	819
1995	166	154	350	66	61	—	0	4,720	108	615	21	6,261
1994	569	471	12	2	0	—		4,124	72	170	0	5,420
1992	479	559	—	0	20	—	200	4,343	600	660	17	6,878
1991	120	550	—	0	0	—	0	2,710	0	995	62	4,437
1990	834	458	—	0	0	—	0	4,400	45	525	0	6,262
1989	830	448	—	0	0	—	0	2,400	48	466	0	4,192
1988	2,390	880	—	0	0	—	6	9,000	119	422	0	12,817
1987	2,761	2,750	—	0	0	—	75	1,500	0	410	0	7,496
1986	1,550	1,200	—	182	0	—	165	14,000	0	1,034	0	18,131
1985	235	696	—	0	5	—	127	5,284	0	208	0	6,555
1978	0	0	0	0	0	0	44	4,020	0	1,589	0	5,653
1977	30	426	0	0	0	0	1,300	3,390	0	865	40	6,051
1976	0	130	11	0	0	0	2,240	910	0	1,486	0	4,777
1975	440	668	16	0	1	0	995	3,055	0	14,555	15	19,740
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	217	1,210	15,525
1973	1,875	1,383	267	0	0	503	500	4,025	0	1,100	18	9,671
1972	1,030	744	0	0	0	0	350	2,610	0	0	1,293	6,027

[a] September count of early spawning kokanee

Shrimp Abundance

The estimated total mean density of shrimp during June 1999 based on the vertical tow method was 738 shrimp/m^2 (Table 9). This included 436 young-of-the-year (YOY) shrimp/m^2 (<10 mm in total length) and 302 immature and adult shrimp/m^2. Density of immature and adult shrimp at the southern end of the lake increased from 149 in 1998 to 235 shrimp/m^2 in 1999. They also increased from 199 to 237 shrimp/m^2 in the center of the lake. At the north end of the lake, densities decreased from 930 shrimp/m^2 in 1998 to 412 shrimp/m^2 in 1999. The whole-lake average of immature and adult shrimp (excluding YOY) declined from last year's mean of 426 shrimp/m^2 to this year's mean of 302 shrimp/m^2 (Figure 11).

In comparison, we estimated the mean density of shrimp to be 1,120/m^2 for the entire lake using the Miller sampler (Table 9). This included 736 YOY shrimp and 384 immature and adult shrimp/m^2. We compared the catch of the two sampling methods at 12 sites (Figure 12). Correlation was high (r^2 = 0.91 for the immature and adult shrimp) with the Miller sampler collecting 1.28 times as many shrimp as vertical net tows.

Egg Incubation Studies

Survival rates of egg baskets varied widely throughout the length of the study. Four of the six control baskets remained intact to the April sampling dates. Their survival rates ranged from 0% to 43%, with a mean of 20% (Table 10). The mean value includes two controls samples at the Hope site that were destroyed by wave action and did not remain intact until April. Mid-April survival of baskets in deep water varied from 0% to 75%, with a mean of 42%. None of the six deep baskets remaining until April were dislodged from their original position. Conversely, only one of the six baskets in shallow water was undisturbed by April. It had a 6% survival rate for the eggs. Of the remaining five baskets in shallow water, two of the baskets from the Hope site were found destroyed and washed up on shore, while the other three were not located. (The three missing baskets were found months later in their original locations, without marker ribbons attached. Apparently the ribbons were torn away from the baskets by wave action or deteriorated due to sunlight.)

Survival rates for baskets retrieved on a monthly basis also varied widely (Table 10). Four of the nine shallow baskets sampled prior to April had been at least partially dislodged upon retrieval and had 0% to 77% survival of eggs, while the five undisturbed shallow ones had survival rates from 0% to 90% to time of retrieval. Only one of the nine deep baskets sampled before April had been disturbed. This basket was the shallowest of the deep group (2 m), and its 4% survival rate reflects the effect of disturbance. The other eight deep samples had survivals between 74% and 100%. All three of the Hope controls retrieved before April had been dislodged, with 0% survival of eggs, while the six from the other two sites were undisturbed. Their survival rates ranged from 85% to 99%.

Analysis of gravel samples taken for each egg basket showed that deep sites tended to have lower concentrations of fine material than the shallow sites at both Scenic Bay and Bernard Beach locations (Figure 13). Substrate at both deep and shallow locations in Hope had low levels of fine material. Deep stations at all three sites tended to have the highest concentrations of cobble material (Figure 13).

Table 9. Densities (per m^2) of shrimp in Lake Pend Oreille, Idaho, using two different collection methods from June 14-16, 1999. Sections are shown in Figure 1.

	Vertical Tow			Miller Sampler		
Section Transect	YOY	Immature and Adults	Totals	YOY	Immature and Adults	Totals
1-05	395.1	222.2	617.3	569.8	393.4	963.2
1-11	251.4	199.8	451.2			
1-15	203.1	128.7	331.8			
1-17	526.9	320.9	847.8	687.8	350.7	1038.5
1-31	322.9	175.3	498.3	540.8	172.1	712.8
1-35	338.5	159.8	498.3	889.4	347.4	1236.8
1-41	742.3	309.1	1051.4			
1-48	676.1	361.3	1037.3			
Section 1 means	432.0	234.6	666.7	671.9	315.9	987.8
2-02	532.6	166.0	698.5	1506.8	309.1	1815.9
2-13	959.7	257.2	1216.8			
2-20	498.3	198.4	696.6			
2-24	442.6	245.1	687.8	1287.3	221.9	1509.2
2-34	694.1	262.3	956.4	822.4	167.3	989.7
2-36	900.5	391.8	1292.4			
2-41	303.1	113.5	416.5			
2-60	423.4	262.8	686.2	887.5	497.5	1385.0
Section 2 means	594.3	237.1	831.4	1126.0	299.0	1425.0
3-02	250.2	185.2	435.5	407.0	244.2	651.2
3-05	294.9	216.7	511.5			
3-10	345.3	303.2	648.5			
3-44	105.4	191.7	297.1	239.9	186.6	426.5
3-49	212.6	106.9	319.5	247.5	195.4	442.9
3-65	494.3	1120.1	1614.4	799.1	1427.9	2227.0
3-66	353.1	806.2	1159.3			
3-79	292.4	368.8	661.2			
Section 3 means	293.5	412.3	705.9	423.4	513.5	936.9
Whole lake means	436.5	301.5	738.1	736.1	383.6	1119.7

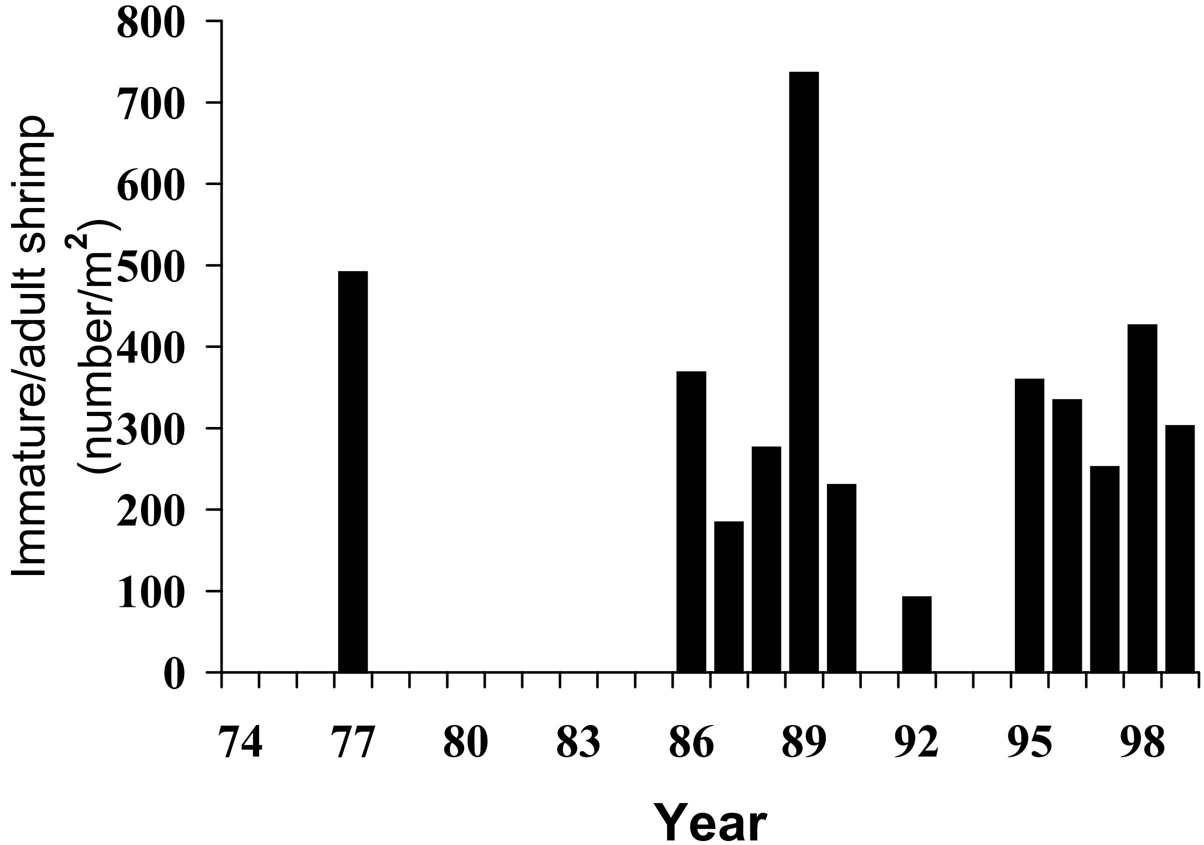
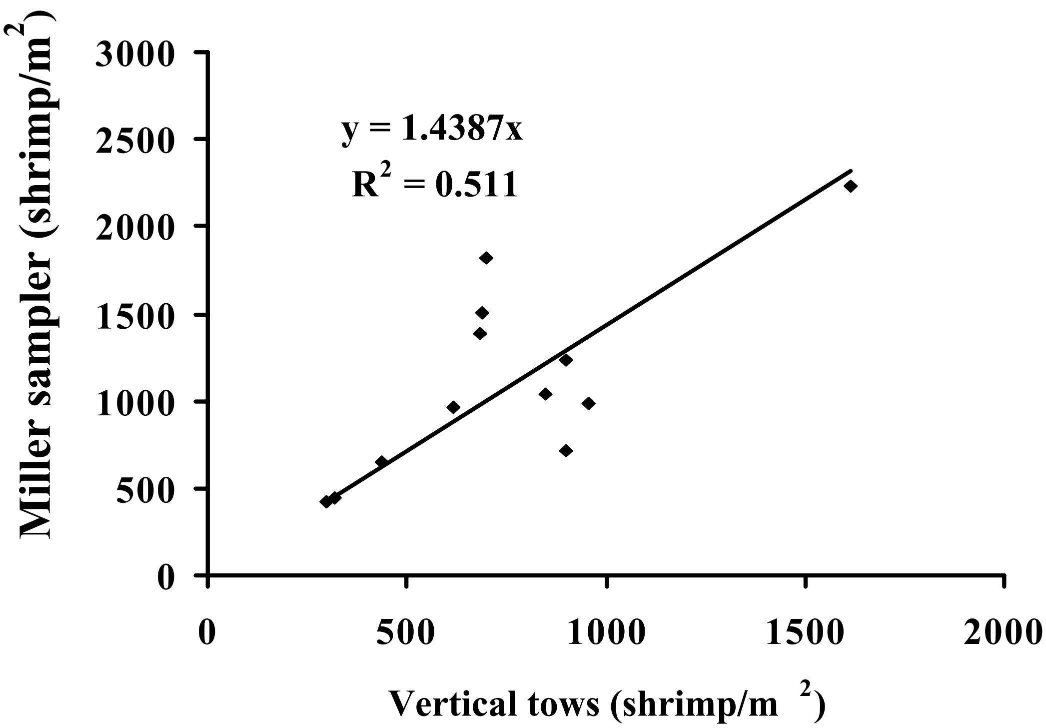


Figure 11. Density of immature and adult opossum shrimp (excluding young-of-the-year shrimp) in Lake Pend Oreille, Idaho, 1977 to 1999. Gaps in the bar chart indicate no data were collected or that the young-of-the-year fraction could not be determined. Pre-1995 data were collected with a Miller sampler. Data collected during 1995 or later were collected with vertical net tows.



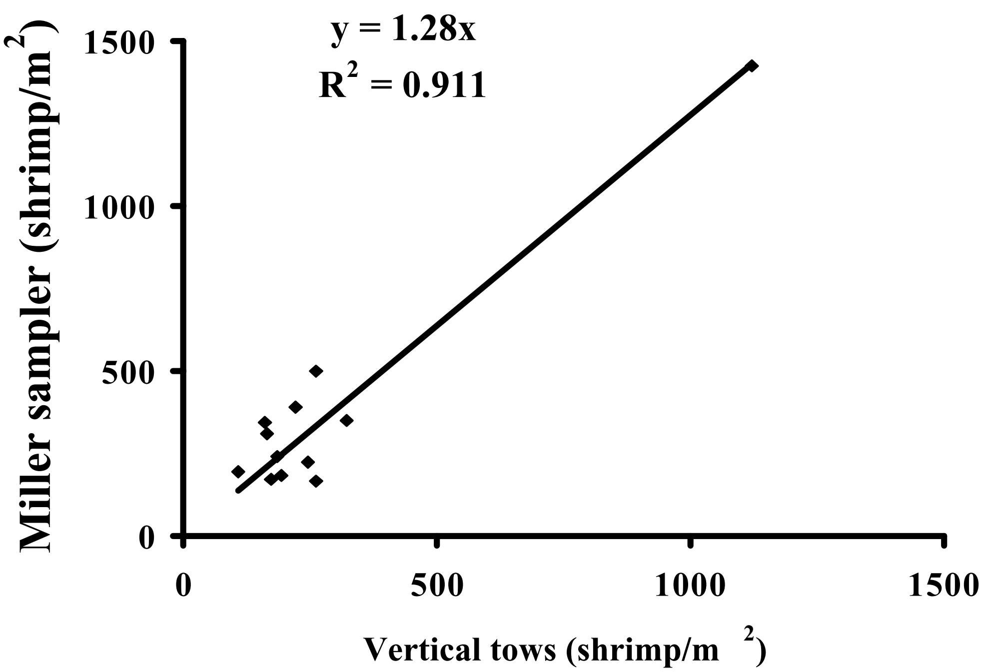


Figure 12. Comparison of Miller sampler and vertical tow catch of shrimp. The y-intercept was set to zero. Top graph is for all shrimp and the lower graph is for immature and adult shrimp (excludes young-of-the-year).

Table 10. Lake Pend Oreille egg incubation baskets, 1999: survival rates and sample identification numbers (ID#).

Sample Location	% Surviving to									
	Jan. 12	ID#	Feb. 8-10	ID#	Mar. 12	ID#	Apr. 8-12	ID#	Apr. 8-12	ID#
Hope control	0%[a]	—	0%[a]	—	0%[a]	—	0%[a]	—	0%[a]	—
Hope shallow	0%[a]	S1	90%	S2	80%	S3	0%[a]	S4	0%[a]	S5
Hope deep	100%	D1	76%	D2	85%	D3	75%	D4	37%	D5
Bernard control	99%	—	98%	—	98%	—	43%	—	24%	—
Bernard shallow	78%	S1	22%[a]	S2	0%	S3	6%[a]	S5	—[b]	S4
Bernard deep	96%	D1	95%	D2	4%[a]	D4	0%	D5	49%	D3
Scenic control	99%	—	93%	—	85%	—	17%	—	36%	—
Scenic shallow	37%[a]	S1	77%[a]	S2	60%	S5	—[b]	S3	—[b]	S4
Scenic deep	100%	D1	88%	D2	74%	D3	20%	D4	70%	D5

[a] Egg tubes found dislodged from original location or partially uncovered by wave action; results may have been affected.
[b] Egg tubes lost, could not be located.

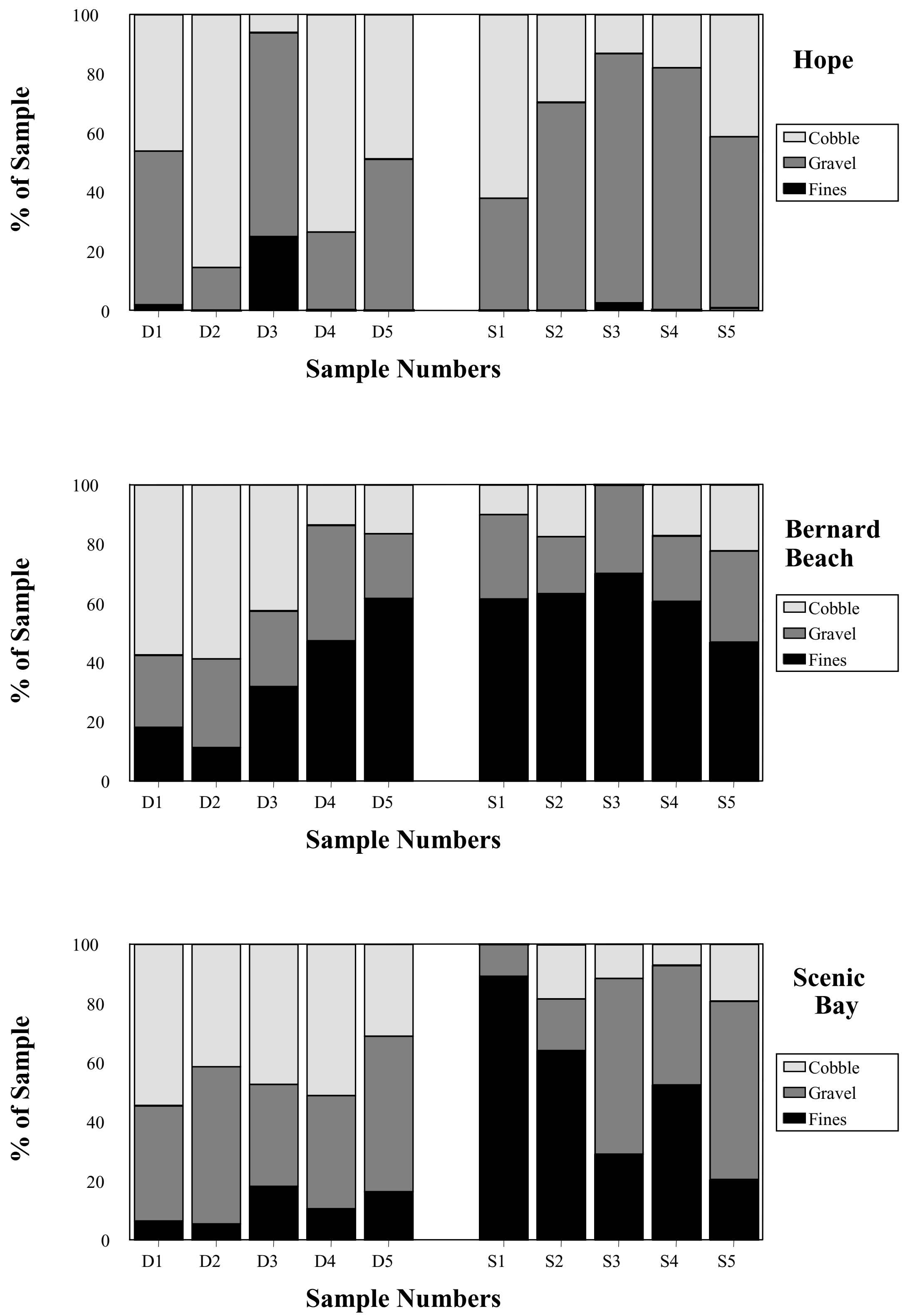


Figure 13. Substrate composition at the site where each egg incubation basket was buried. Sample numbers (on X axis) can be cross-referenced with the survival rates in Table 10.

Limnology

Secchi transparencies averaged 5.5 m at the northern end of Lake Pend Oreille versus 6.8 m and 7.1 m at the middle and southern sections, respectively (Table 11). During spring runoff in June, transparency dropped to its lowest point of 2.5 m at the mid-lake station. The maximum Secchi depth of 13.3 m was recorded at the mid-lake station during April.

Table 11. Secchi disk transparencies (m) at three locations in Lake Pend Oreille, Idaho, 1953, 1974, 1997, 1998, and 1999.

Location	April	May	June	July	Aug.	Sept.	Oct.	Mean
Southern station								
1953	11.9	8.0	3.7	6.1	11.6	8.5	12.8	8.9
1974	8.8	7.6	3.7	3.9	9.2	9.1	9.3	7.4
1997	12.5	4.0	2.7	6.5	8.2	9.0	6.2	7.0
1998	9.0	6.0	4.0	5.5	11.0	9.5	7.75	7.5
1999	11.2	7.0	2.7	5.6	7.3	8.3	7.5	7.1
Mid-lake station								
1953	—	—	3.7	6.1	10.7	12.2	12.2	—
1974	—	5.5	2.3	4.7	9.8	9.4	11.6	—
1997	16.5	5.2	2.0	5.0	7.9	6.8	8.0	7.3
1998	9.0	4.5	3.5	6.0	11.5	10.0	7.0	7.3
1999	13.3	5.5	2.5	6.5	6.9	7.0	6.0	6.8
Northern station								
1953	3.0	3.7	0.9	6.4	9.4	11.0	10.4	6.4
1974	4.0	0.9	0.4	2.8	9.4	10.2	11.6	5.6
1997	5.3	0.7	1.0	4.0	8.5	5.8	5.5	4.4
1998	5.5	3.2	1.2	4.1	10.0	7.5	6.5	5.4
1999	5.9	4.0	2.8	5.0	6.0	7.5	7.5	5.5

Surface water temperatures in the lake ranged from 4.7°C during April (the first month temperatures were taken) to a high of 21°C during August 1999 (Figure 14). Stratification began in late June with water temperatures exceeding 18°C in the northern section. Stratification broke down in late September to early October. Water over 14°C (the upper maximum temperature utilized by opossum shrimp) reached a depth of 18 m in the northern section, 20 m in the middle section, and 19 m in the southern section during the September 15 survey.

Dissolved oxygen concentrations were similar among all three stations in 1999. Concentrations ranged from 11.2 mg/l in May to 8.6 mg/l in September on the south end of the lake, from 11.2 mg/l in May to 8.5 in September at the mid-lake station, and from 11.6 mg/l in June to 8.3 mg/l in September at the northern station. As expected, dissolved oxygen readings declined as water temperature increased.

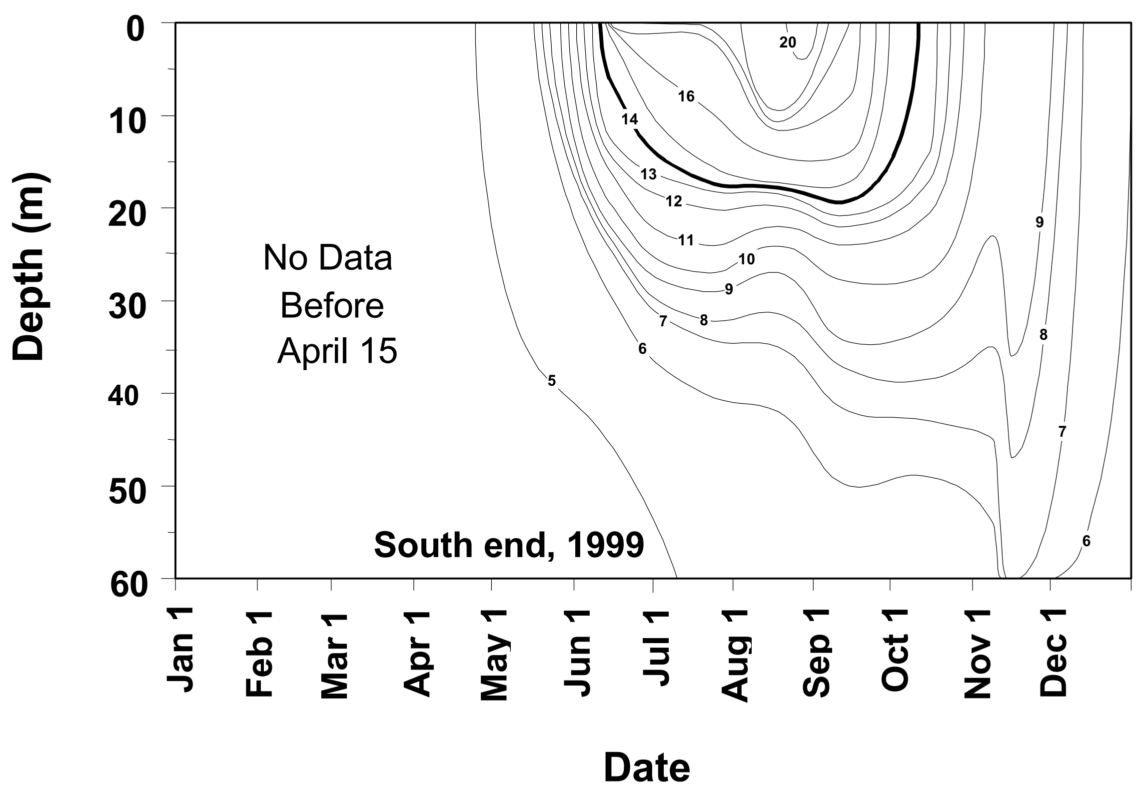


Figure 14. Isopleths of water temperature (C°) in Lake Pend Oreille, Idaho in 1999.

Gravel Sampling

Sixty-six samples of gravel were collected and analyzed at five separate locations (Figure 15) (Appendix B). Substrates varied from very poor spawning potential (100% cobble at most sites in Hope) to very high quality spawning gravel (81% gravel with 8% fines in Ellisport Bay). Gravel quality varied substantially between sites and between elevations at an individual site.

Only at the site near North Gold Creek did we find more than 50% of the substrate was gravel at elevations between 625.1 m and 625.5 m (Figure 15). Substrate at other sites contained less than 25% gravel at these elevations.

Riparian Areas

There were no observable changes in riparian vegetation at our sampling sites in the drawdown zone of the lake (between the elevations of 628.7 m and 625.8 m). After three growing seasons with changed water levels, the drawdown zone remains devoid of riparian vegetation, and no site showed signs of being re-colonized (Figure 16).

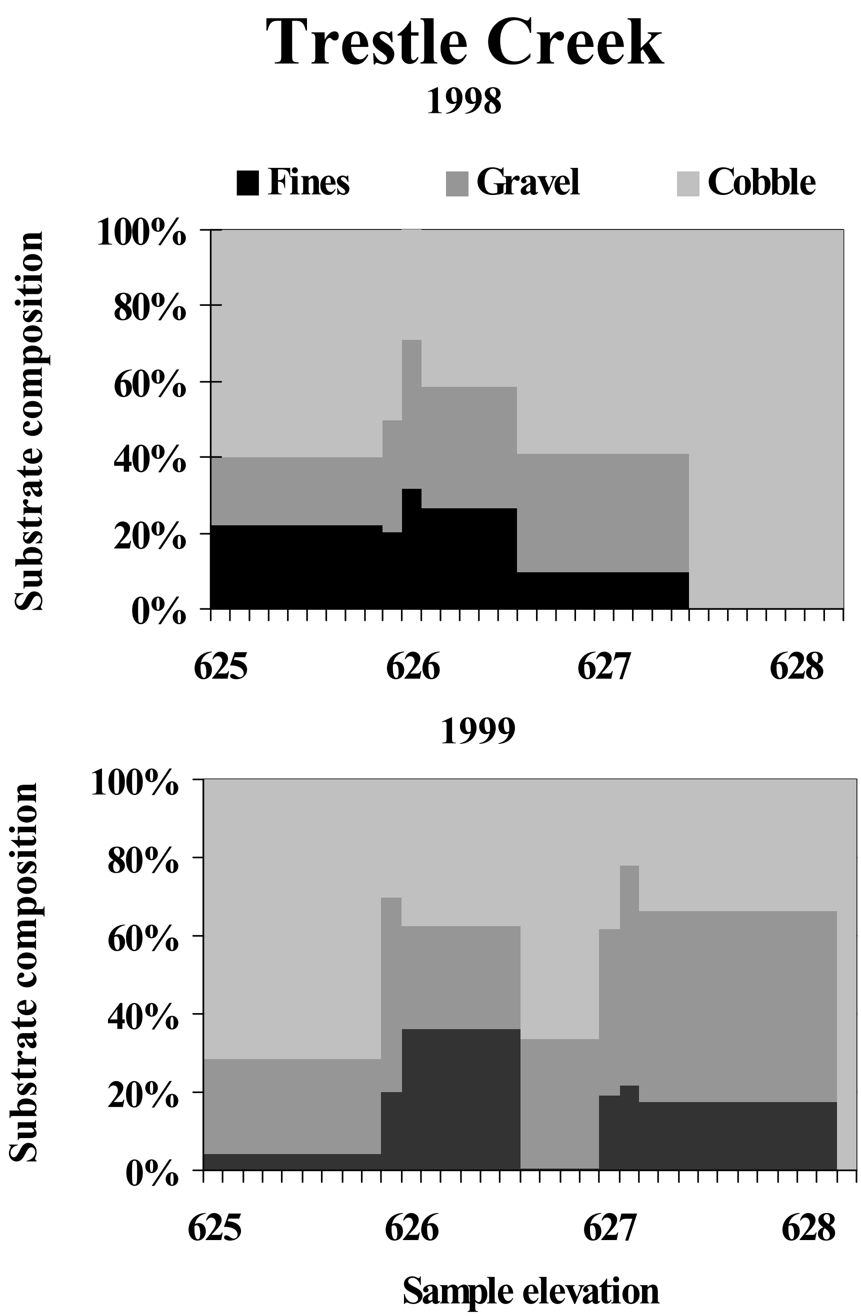


Figure 15. Comparison of substrate composition between two samples taken on the shore of Lake Pend Oreille, Idaho in 1998 and 1999.

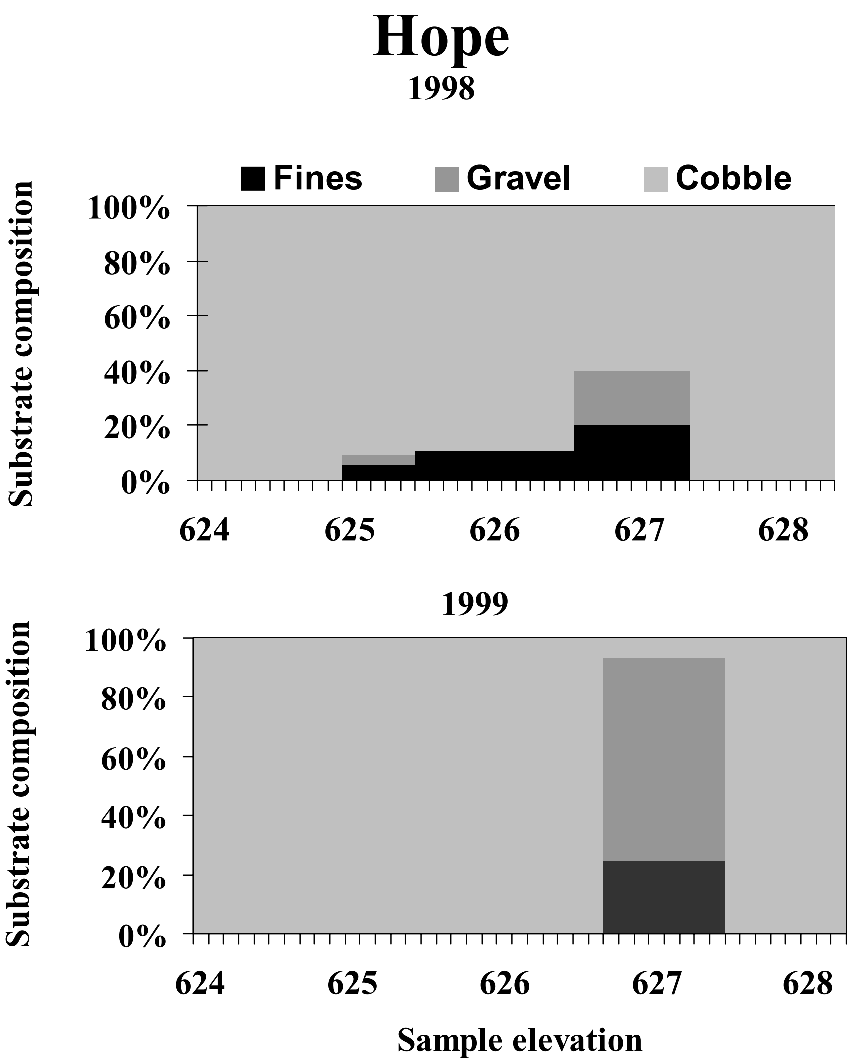
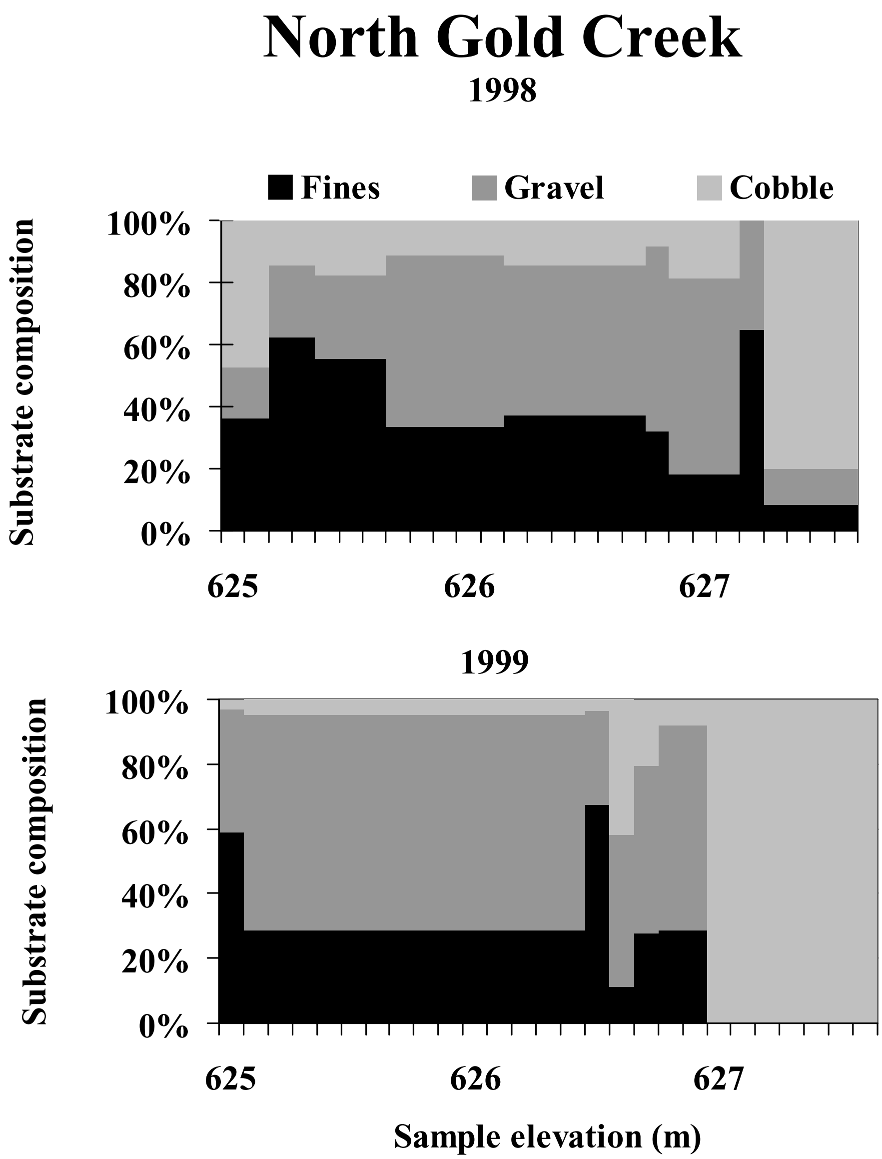


Figure 15. Continued



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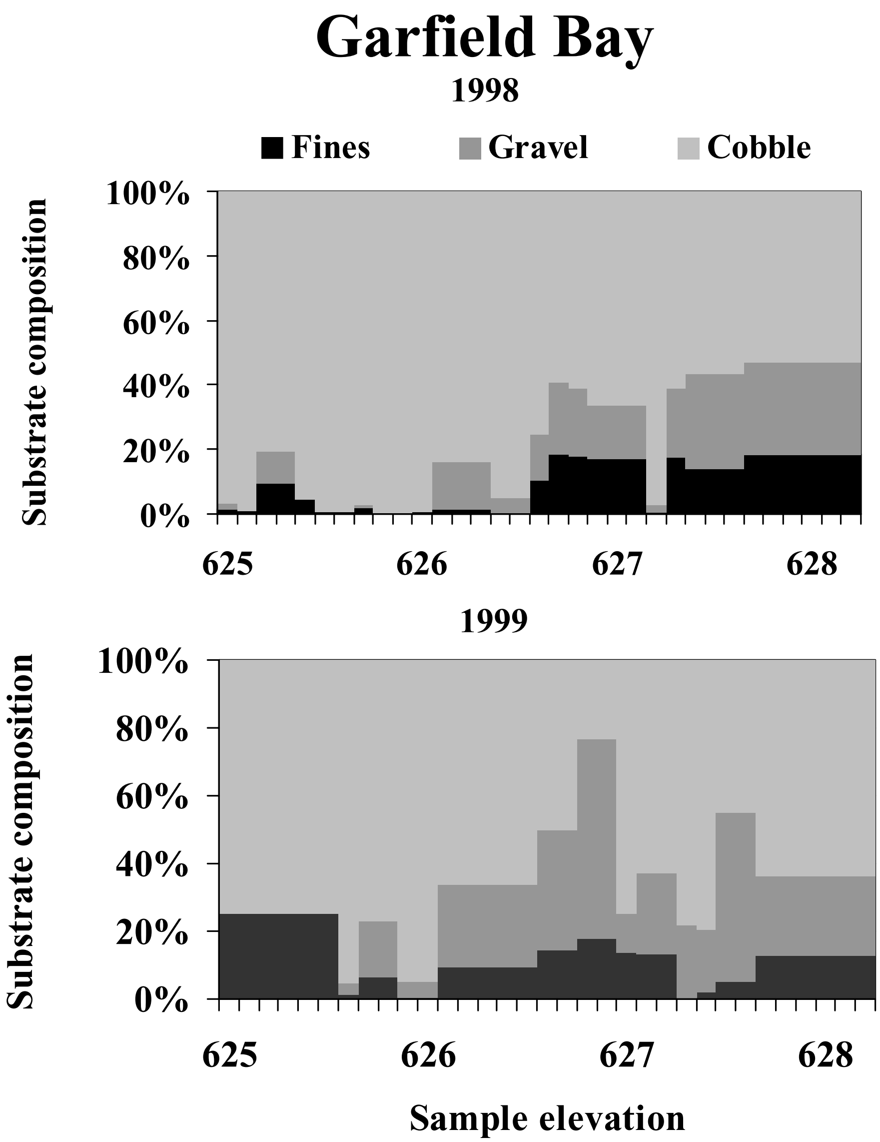

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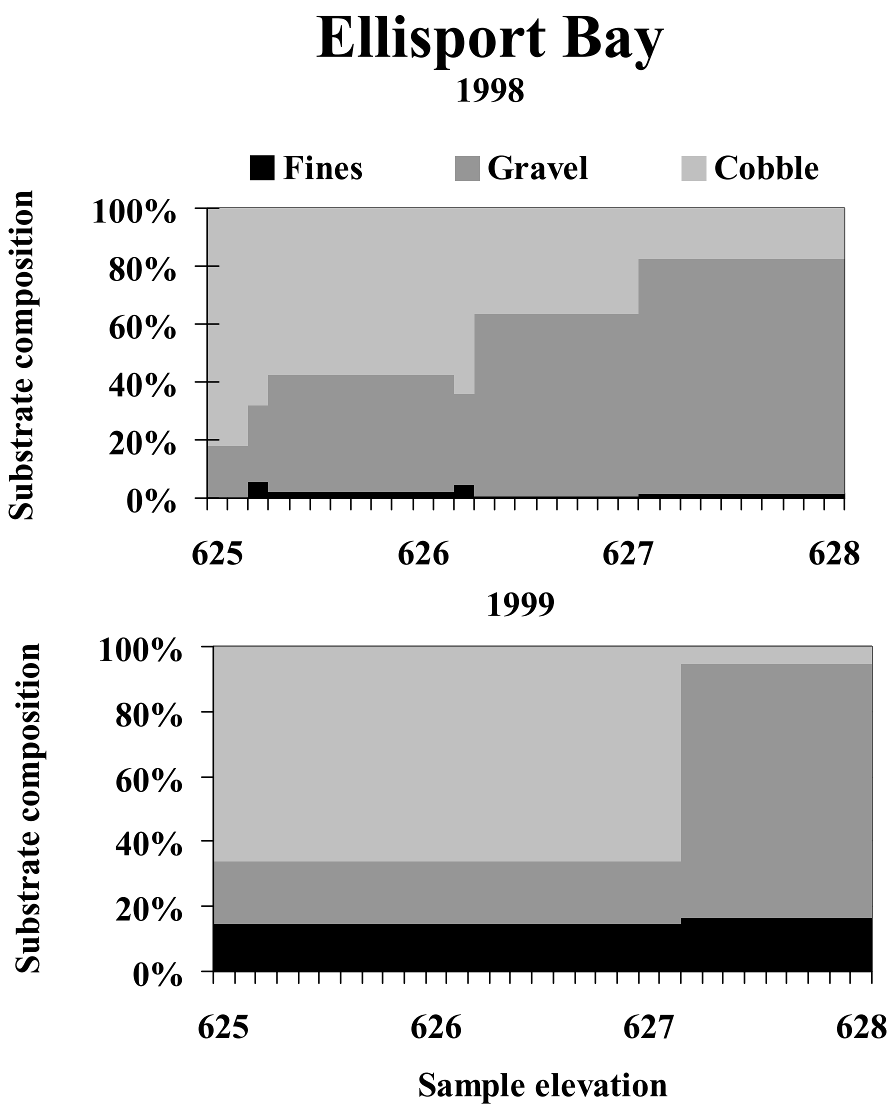

Figure 15. Continued

DISCUSSION

Kokanee Abundance

Nineteen ninety-nine was the last year of the scheduled three-year test of higher winter lake levels. Survival of wild-spawned eggs to kokanee fry was again higher than expected (6%) (Table 4). This was a marked improvement from the survival calculated in 1995 (1.4%), before any changes in lake levels. It was also substantially better than the survival calculated in 1996 (4.3%). In that year the lake was raised during the middle of the kokanee spawning season. Improvements in egg-to-fry survival up to the 9.7% estimated last year or the 6.0% estimated this year could lead to substantial increases in the kokanee population and the eventual recovery of this important fishery.

The spring of 1997 was the wettest on record, and kokanee survival in most age classes was unusually low. Excluding 1997, there was a 274 % improvement in kokanee survival from 1995 and 1996 to 1998 and 1999 (means of each group). If all other causes of mortality stayed the same, this would lead to nearly a tripling of harvestable-sized kokanee in the first generation. This could lead to a nine-fold increase in kokanee in the second generation, if other causes of mortality remained unchanged. This magnitude of increase in survival, therefore, could lead to a geometric expansion of the population. However, at some point compensatory factors will stop this rate of increase.

In 1995, when the proposal for this project was written, we stated that the study would be considered a success if egg-to-fry survival increased from a mean of 2.47% to >3.1%. Kokanee survival exceeded this criterion for two of the last three years. We, therefore, should be cautiously optimistic that the changed lake levels were having a positive effect on kokanee survival. A needed part of the test would be to change lake levels at a time when adult kokanee abundance is much higher. This would demonstrate that the improvement in survival is not dependant on low kokanee densities.

In the previous years, we reported on several key findings that demonstrated why higher fall-winter lake levels would improve kokanee survival (Maiolie et al. 1999). Kokanee readily utilized the new gravel that was made available by higher lake levels. This gravel was cleaner, which should have improved the survival of incubating eggs by providing them with more oxygen and allowing waste products to be carried away (Bjornn 1969). Kokanee also appeared to utilize much of the southern half of the lake for spawning. Although not previously mapped, most kokanee were thought to be spawning in the Scenic Bay area as evident in the spawner counts (Table 5). The spreading of spawning activities would have dispersed kokanee redds and minimized their superimposition. This also could have dispersed the fry around the lake, which would minimize the potential for intra-specific competition and may have reduced the potential for predators to key in on kokanee fry. During 1999, most kokanee spawned primarily at the south end of the lake (Figure 9). We suspected that with lower numbers of kokanee spawners there was less of a tendency for kokanee to spread toward the northern end of the lake.

We determined that the peak of kokanee spawning occurred at a depth of 1 m in 1999 (Figure 10). This corresponded to the depth of the old shoreline of the lake (pre-1996) at an elevation of 625.1 (2051 ft). This is the point of the deepest gravel that was made available by raising the lake level. Possibly, kokanee were seeking the deepest clean gravel that was present in the area into which they homed. Results of our egg incubation tests (Table 10) indicated that eggs buried in less than 1 m of water were in risk of being dislodged by wave action. This would indicate a selective advantage for kokanee spawning below this depth.

Although the survival from kokanee eggs to fry has improved, the survival rate for kokanee from age-1 to age-2 remains alarmingly low (Table 5). Percent survival dropped from nearly 100% in 1996; to 22% in 1997; to 29% in 1998; to 16% in 1999 (Table 5). The drop in 1997 could have been due to the flooding that year. We hypothesize that low survival in the two most recent years is due to predation. Even if predators eat the same mass of prey each year, the percent survival of kokanee would decline as the population drops. Kokanee of age-1 and -2 were the year classes most commonly found in the stomachs of predators (Vidergar 2000). Vidergar (2000) estimated that rainbow trout, lake trout, and bull trout collectively consumed 154 metric tons of kokanee in 1998. If consumption of kokanee remained the same during 1999, then predators consumed 60% of the total kokanee production for 1999. Rieman and Myers (1991) suggested that predator consumption exceeding 50% of the annual production would pose a high risk of collapsing a kokanee population.

Fry Netting

We found that using the fry net was an effective method to collect representative samples of kokanee fry in Lake Pend Oreille. Results with the fry net were somewhat different than results with the trawl net (Figure 7). The fry net was more effective at sampling the smaller fry, which are more likely to be of wild origin. Thus the fry net yielded higher density estimates of wild kokanee fry than did the trawl net, because the trawl net contained panels of large mesh netting in the front, which graduated down to 6 mm mesh in the cod end. Kokanee of less than about 40 mm appeared to have gone through the mesh in the trawl net. The proportion of wild to hatchery fry was, therefore, thought to be more realistic with the fry net. Splitting the hydroacoustic estimate of fry into wild and hatchery components based on the fry net yielded an egg-to-fry survival rate of 9.1%. However, 1999 was the first year this net was used, so no comparisons could be made to previous years. We therefore estimated the number of kokanee fry in the lake using hydroacoustics and split the estimate into its wild component based on the percent of wild fry collected during mid-water trawling. Similar data has been collected since 1995 and will be used in the completion report to evaluate lake level changes.

Total population estimate of wild fry, based on what was caught in the fry net, was 3.189 million (Table 6). This estimate is higher than the 2.573 million wild fry estimated using hydroacoustics. The hydroacoustic estimate is lower because it utilized the percent of wild fry in the trawl net, which underestimated the smaller fry. Mid-water trawling yielded a wild fry population estimate of 1.484 million. This was likely the least accurate method to estimate wild fry abundance.

We caught only one fish that was not a kokanee with the fry net during the 15 hauls. This one whitefish could have been collected while the net was being set or retrieved so it may not have been caught in the pelagic kokanee layer. Therefore, we did not adjust the hydroacoustic estimate for fry that were not kokanee.

Redd Mapping

Most of the kokanee redds in Lake Pend Oreille are at the extreme southern end of the lake. This was likely where most of the kokanee originated, so they were returning there to spawn as adults. This finding is in stark contrast to kokanee spawner counts in 1952 and 1953 when the largest concentration of kokanee was spawning on the north shoreline. Jeppson (1954) estimated that 20,000 to 25,000 kokanee spawned at West Hope on the lake's north shoreline. Consistent drawdowns of the lake to an elevation of 625.1 m (2051 ft) were found to leave most of the suitable shoreline spawning gravel above the waterline in this section of the lake (Maiolie and Elam, 1993). Limited spawning habitat five years ago (1995) could have resulted in the low numbers of kokanee seen there in 1999.

Shrimp Abundance

We monitored the shrimp population to determine if changes in shrimp abundance could be affecting kokanee survival. If large changes in the shrimp population occur, then it could have an affect on the experiment's outcome. In 1999, the shrimp population returned to a near average density (Figure 11). To date, shrimp did not show a trend throughout this test that would explain the increases in kokanee egg-to-fry survival. At the end of the test, kokanee survival rates will be regressed against shrimp abundance to look for a correlation.

Young-of-the-year shrimp in Lake Pend Oreille exert little predation mortality on crustacean zooplankton and do not become potential competitors with kokanee until they reach a length of >8 mm (Chipps 1997). Accordingly, the density of immature and mature shrimp provides the best guideline for interpreting potential competition. Immature and mature shrimp in Lake Pend Oreille reached $302/m^2$ in 1999; down from $426/m^2$ in 1998 (Figure 11). This brought their mean density down to slightly below the mean of the last five years (335 shrimp/m^2).

Egg Incubation Studies

The original intent of the egg incubation study was to determine if kokanee eggs that were buried in shallower water with cleaner substrate would have an increased survival rate. The improvement we were looking for was about 3% to 8%, based on the survival rate increases seen when the lake was held higher. Results of our test were too variable to detect a 3% to 8% change. Baskets at the same site at the end of the experiment had as much as a 50% difference in survival rate.

Baskets of eggs used for control samples were expected to have the best survival rate since they were placed into an area where the substrate was screened to be free of fine material. However, controls at the Hope site were dislodged by wave action and had 0% survival; controls at other sites were not consistent, and at Scenic Bay, controls had lower survival than the test group in deep water (Table 10).

Another finding of the test was that eggs buried in less than 1 m of water along the main shoreline run a substantial risk of being dislodged by wave action. On exposed sites, wave action was severe, completely dislodging, and in some cases destroying, egg baskets buried in 1 m or less of water. We assume that the same fate befalls naturally deposited eggs at similar depths. This would indicate that the minimum lake level should vary by at least 1.2 m (4 ft) to create clean gravel that is deeper than the zone affected by wave action.

Some of the observed variability in egg survival appeared to be associated with the quality of the substrate into which the eggs were placed. For example, at the Bernard Beach site in the deep-water samples (Table 10), survival was exceptionally poor in samples D4 and D5 that contained fine material of 47% and 62%, respectively. Egg survival was much better at this location when fine material made up less than 32% of the substrate as in samples D1, D2, and D3.

Limnology

We monitored basic parameters of physical limnology to determine if they influenced the outcome of the lake level experiment. We wanted to know if unusually warm or cold years would affect survival of fry and possibly bias the test results. Surface temperatures in 1999 were fairly normal and reached 21°C (Figure 14). Warm water (over 14°C) persisted to early October and provided a normal growing season for zooplankton and kokanee. Limnological results will be more meaningful once the five years of this study are completed and individual years can be compared to the survival of kokanee fry.

Gravel Sampling

Core samples of gravel collected in 1999 were compared with samples collected in 1998 (Figure 15). The trend seen the last few years towards a decline in the quality of the gravel for spawning appears to be continuing for sites located on the shoreline away from the influence of tributary streams. These sites show very limited spawning habitat between the elevations of 625.1 and 626.4 m. At the completion of this study, the quality of spawning gravel at each site will be compared since the study began.

Riparian Areas

Higher winter lake levels did not cause a recolonization of vegetation in the drawdown zone (Figure 16). Since the drawdown zone is underwater during the summer growing season and exposed to freezing temperatures during winter, it remains an inhospitable habitat for riparian vegetation. Having a higher winter pool level during our test years (1996, 1997, and 1998) did not cause any noticeable change in riparian vegetation.

This area was heavily vegetated before the lake's impoundment by Albeni Falls Dam. Vegetation could colonize the area because water levels would drop towards the low pool elevation shortly after spring runoff. The area was then above water for much of the growing season, and was good habitat for riparian vegetation.

RECOMMENDATIONS

1. We recommend continuing the lake level experiment as planned.

Farragut 1999

Leiberg Pt. 1999

Idlewild Bay 1999

Bernard 1999

Sand Creek 1999

Denton Slough 1999

Figure 16. Photographs of nine shoreline areas around Lake Pend Oreille, Idaho at a winter elevation of 625.7 m (2,053 ft), December 1999. Note the lack of riparian vegetation between the high and low pool elevations.

Sandpoint 1999

Trestle Creek 1999

West Trestle Ck 1999

Figure 16. Continued.

ACKNOWLEDGMENTS

Many people contributed to making this study possible. Biological aides Mark Duclos and Eric O'Brien assisted with many of the field activities and the maintenance of equipment. Mike Fields and Todd Maddock of the Northwest Power Planning Council were instrumental in getting this project approved. Ned Horner, Regional Fishery Manager, Dr. Dave Bennett, University of Idaho professor, and Hobart Jenkins, retired professor and community leader, assisted with the biological understanding of Lake Pend Oreille and lent support for the project’s design. The authors would like to thank the U.S. Army Corps of Engineers for making the needed lake level changes. The Bonneville Power Administration provided funding for this study and we wish to thank Charlie Craig for his help in administering our contract. Kimberly Harding and Ned Horner edited drafts of this report. The help of these people and agencies was greatly appreciated.

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APPENDICES

Appendix A. Definition of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille since 1972.

Scenic Bay

- From Vista Bay Resort to Bitter End Marina (the entire area within the confines of these two marinas).

Farragut State Park

- From state park boat ramp go both left and right approximately 1/3 km.
- Idlewild Bay from Buttonhook Bay north to the north end of the swimming area parking lot.

Lakeview

- From mouth of North Gold Creek go north 100 meters and south ½ km.

Hope/East Hope

- Start at the east end of the boat launch overpass and go west 1/3 km.
- From Strong Creek go west and stop at Highway 200. Go east to Litehouse Restaurant.
- Start at East Hope Marina and go west stopping at Highway 200.

Trestle Creek Area

- From the Army Corps of Engineers recreational area boat ramp go west to mouth of Trestle Creek, including Jeb and Margaret's RV boat launch area.

Sunnyside

- From Sunnyside Resort go east approximately ½ km.

Garfield Bay

- Along docks at Harbor Marina on east side of bay.
- From the Idaho Fish and Game managed boat ramp go toward Garfield Creek. Cross Garfield Creek and proceed ¼ km.
- Survey Garfield Creek up to road culvert.

Camp Bay

- Entire area within confines of Camp Bay.

Fisherman's Island

- Entire Island Shoreline—not surveyed since 1978.

Anderson Point

- Not surveyed since 1978.

Appendix B. Weights (g) of substrate samples from potential shoreline spawning areas on Lake Pend Oreille, Idaho, 1999.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (625.1 m/2051 ft) to top of band (m) (ft)	Size Fractions (mm) >63.5	31.75-63.50	16.00-31.75	9.50-16.00	6.35-9.50	2.00-6.35	0.84-2.00	<0.84
Hope 1999										
Rip	628.5	19.8	100%							
Rap	2062.2	64.9								
A	627.4	19.8	0	96	683	341	318	975	175	65
	2058	64.9	0	145	706	360	146	49	1	3
B	626.6	16.5	1689	276	0	0	0	0	2	15
	2056	54.2	1958	0	0	0	0	0	0	9
			913	333	0	0	0	0	1	6
			3500	0	0	0	0	0	0	0
Bottom of	624.0									
Band B	2047.2									
Garfield Bay 1999										
A	628.5	19.5	363	675	379	74	24	62	73	44
	2062.2	64	0	1106	206	62	34	95	95	59
B	627.6	18.3	0	982	626	64	27	46	65	70
	2059.3	60	0	853	633	750	118	7	4	4
C	627.3	17.1	478	1235	0	0	0	0	0	0
	2058.3	56	0	944	422	153	39	33	20	16
D	627.3	15.9	0	780	463	131	7	0	0	0
	2058.3	52	0	1766	0	0	0	0	0	0
E	627.2	14.6	0	1058	384	193	99	315	197	26
	2057.8	48	639	1412	319	97	54	52	10	1
F	627.0	13.4	912	663	159	60	26	77	36	7
	2057.0	44	891	430	126	41	227	149	208	55
G	626.9	12.2	0	553	775	193	80	91	7	2
	2056.7	40	0	273	524	309	235	512	61	8
H	626.7	11.0	0	824	361	80	29	68	58	15
	2056.2	36	0	1057	589	184	178	375	73	15
I	626.5	1.0	486	274	184	0	6	1	1	1
	2055.5	32	0	1421	408	210	147	279	158	51
J	626.0	8.5	824	319	0	0	0	0	1	3
	2053.8	28	574	476	104	5	0	0	0	1
K	625.8	7.3	640	421	241	75	44	57	45	34
	2053.2	24	2032	196	192	39	15	33	48	34
L	625.6	6.1	1131	111	14	28	46	6	10	14
	2052.6	20	750	471	0	0	0	1	1	4
M	625.5	4.9		75 percent						25 percent
	2052.3	16								

Appendix B. Continued.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (625.1 m/2051 ft) to top of band (m) (ft)	Size Fractions (mm)							
Garfield Bay 1999, Continued.										
N	625.4	3.7	75 percent							25 percent
	2051.8	12								
O	625.2	2.4	75 percent							25 percent
	2051.4	8								
P	625.2	1.2	75 percent							25 percent
	2051.3	4								
Q	625.1	0	75 percent							25 percent
	2051.0	0								
R	625.1	-1.2	75 percent							25 percent
	2050.9	-4								
S	625.0	-2.4	75 percent							25 percent
	2050.6	-8								
T	624.9	-3.7	75 percent							25 percent
	2050.3	-12								
Trestle Creek 1999										
	628.5		100 % Rip Rap							
	2062.2									
A	628.2	46.7	765	163	347	133	224	8	5	1
	2061.2	153.2	0	291	877	412	227	407	260	275
B	627.1	39.1	0	302	428	202	76	125	55	49
	2057.6	128.2	0	538	1120	452	242	335	192	188
C	627.1	33.2	0	447	786	167	213	197	208	141
	2057.6	108.8	666	451	397	153	58	108	62	86
D	626.9	29.3	0	948	898	94	29	7	0	1
	2056.8	96	2733	674	331	108	170	10	2	7
E	626.5	24.7	0	119	326	84	64	107	59	437
	2055.4	81.1	1783	267	413	0	0	228	73	386
F	625.9	17.8	0	0	490	637	373	67	42	289
	2053.7	58.3	0	1323	226	165	59	96	49	280
G	625.8	14.8	0	727	290	96	54	46	16	30
	2053.3	48.4	2061	798	365	78	22	14	4	22
Bottom of	624.7	-8.75								
Band G	2049.6	-28.7								
North Gold Creek 1999										
A	628.5	72.5	100	0	0	0	0	0	0	0
	2062.1	237.7	100	0	0	0	0	0	0	0
B	626.9	62.7	0	301	786	327	198	368	85	31
	2057.0	205.8	0	57	621	590	535	841	61	41

Appendix B. Continued.

Band	Elevation to top of band (m) (ft)	Distance from old waterline (625.1 m/2051 ft) to top of band (m) (ft)	Size Fractions (mm)							
North Gold Creek 1999, Continued.										
C	626.7	53.1	0	563	414	173	76	214	96	53
	2056.3	174.1	0	104	343	446	360	582	15	12
D	626.4	50.4	0	213	567	257	106	130	49	90
	2055.2	165.3	447	761	321	133	49	46	4	5
E	626.3	34.8	0	567	668	423	276	417	93	119
	2054.8	114	0	268	760	539	252	325	88	48
F	626.4	29.7	0	57	268	119	92	787	616	110
	2055.3	97.5	0	128	227	308	445	1335	292	80
G	626.5	25.3	0	139	600	193	117	145	70	117
	2055.4	83	0	0	454	193	127	188	86	109
H	625.1	0	0	179	488	406	367	706	239	302
	2051	0	0	0	86	179	188	504	225	409
Bottom of Band H	624.8	-4.6								
	2050.1	-15								
Ellisport Bay 1999										
A	628.52	13.54	0	1519	316	67	3	0	0	0
	2062.2	44.4	482	170	383	79	61	41	0	1
B	627.1	10.67	0	1101	237	119	120	284	0	1
	2057.6	35.0	0	848	158	90	154	1077	1	3
C	625.0	-.85	0	2095	263	7	1	0	0	0
	2050.5	-2.8	0	736	343	63	58	495	1	2
D	624.9	-5.4	0	208	331	668	615	167	0	0
	2050.3	-17.7	0	0	118	225	511	273	0	0
Bottom of Band D is unknown										

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